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Currency futures' risk premia and risk factors

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1866

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Currency Futures' Risk Premia and Risk Factors

Kerstin Bernoth*, Jürgen von Hagen†, Casper G. de Vries‡

April 29, 2020

Abstract

The use of futures exchange contracts instead of forwards completes the maturity spectrum of the correlation between the spot yield and the premium. We find that the forward premium puzzle (FFP) depends significantly on the maturity horizon of the futures contract and the choice of sampling period. The FFP appears to be a pre-crisis phenomenon and is only observed for maturities longer than about one month. When examining whether the observed excess returns of futures contracts represent a fair compensation for currency risk, we find that non-durable consumption risk and market risk can explain excess currency returns. But only in the pre-crisis period and when the maturity of the assets is longer than about three months.

Keywords: forward premium puzzle, uncovered interest parity, futures rates, risk premium, currency excess returns, capital asset pricing model.

JEL Classification: F31, F37, G12, G13, G15

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1 Introduction

According to the Expectations Hypothesis (EH), forward exchange rates should be unbiased predictors of future spot exchange rates. The hypothesis is an important building block of models of international macroeconomics and finance and manifests itself also in the form of the well-known uncovered interest parity (UIP) condition. The empirical support, however, is weak at best. Fama (1984) was the first to report that in a regression of foreign exchange returns on forward premiums, the estimated slope coefficient is negative rather than one. Since then a large body of empirical research has investigated what today is known as the ‘forward premium puzzle’ (FPP).

The empirical literature falls into three categories. The first category gives estimates at very short maturities at the intra-day or overnight horizon, see e.g. Chaboud and Wright (2005) and Yang and Shintani (2006). A second category looks at the other end of the spectrum, even going as far as considering multi-year horizons. Papers that fall into this category are Alexius (2003), Chinn and Meredith (2004), and Fama and Bliss (1987), and more recently Engel (2016).¹ Most papers focus on intermediate horizons by using monthly forward data starting at one month up to several months. Examples in this category are Froot and Frankel (1989), Backus et al. (2001), Baillie and Kilic (2006), and Clarida et al. (2009).

The summary finding from these papers is that the EH may hold at the very short term and in the very long run, but significant deviations are reported at intermediate periods, mostly negative and sometimes positive. At intermediate periods, however, the evidence is rather granular as it contains relative long gaps since monthly data are used, so that only evidence at the one month, two month etc. horizons is available. A first contribution of this paper is to fill this gap. We report estimates for maturities at a daily frequency, with maturities ranging from one day up to multiple months, yielding estimates at a much finer grid than is currently available. This is possible thanks to using futures data instead of forward data. Only the early paper by Hodrick and Srivastava (1987) uses data from three-months futures contracts to test a hypothesis related to the EH. It presents evidence rejecting this hypothesis. To the best of our knowledge no paper has exploited these data to obtain the estimates at the daily grid level.

While data for forward contracts are available only for fixed maturity *horizons*, futures contracts have fixed delivery *dates*. Since futures contracts are traded in secondary markets, this makes it possible to analyze futures rates from the first to the last trading day of a given contract and to construct the full maturity spectrum of futures premiums in daily units. While differences in trading mechanisms, default, or liquidity premiums between forward

¹It is worth mentioning that Engel (2016) attributes the multi-period excess return to the one-period interest rate differentials. Therefore, the maturities of assets and interest rates do not coincide.

and futures contracts might somewhat cloud the comparability of the two, empirical studies suggest that this is not the case.²

We examine the behavior of exchange rates for the United States relative to all countries for which currency futures have been traded at the Chicago Merchantile Exchange. These comprise nine developed countries and six emerging market economies. The time period covered is 1979Q1 to 2018Q4 and we consider futures rates with a time to maturity ranging between one day and one and a half years.

We find that the slope coefficient in the Fama regression depends significantly on the maturity horizon of the futures contract and on the choice of sampling period. For maturities shorter than about a month it is generally positive, and the EH is not rejected by the data. For longer maturity horizons, however, the sign and also size of the slope coefficient depend on the time period covered. Focusing on the period before the global financial crisis, the slope coefficient tends to become negative as the maturity horizon over which expectations are formed increases. This finding is in line with the often described FFP and indicates that a country with a higher interest rate has positive excess returns as its currency tends to appreciate in contrast to the prediction of UIP. When focusing on the post-crisis period, however, we cannot reject the validity of the EH for most currencies and maturities. In the few cases where there are significant deviations from the EH during this period, these are upward rather than downward: A country with the relatively lower interest rate is inclined to appreciate much more than the futures premium indicates, compared to the country with the higher interest rate. All in all, we confirm the findings by Thornton (2007) and Kim et al. (2017) that violations of the EH or UIP vary considerably across periods. More specifically, we find that the FFP/ UIP violation appears to be very much a pre-crisis phenomenon for most currencies and is only evident for medium to longer maturities.

A second contribution of the current paper is that we test for a wide range of maturities, whether the observed excess returns on futures contracts indeed reflect a fair compensation for currency risk.³ According the capital asset pricing model (CAPM) of Sharpe (1964), Lintner (1965) and Black (1972), expected excess returns should be equal to a risk premium times the amount of risk of each asset. The static CAPM model measures riskiness of an asset by the covariance of its return with the return on the market portfolio (Jensen, 1972). In the intertemporal CAPM, the riskiness of an asset is measured by the covariance of its return with the marginal rate of substitution of consumption over time, which is most commonly specified as a function of the growth rate of consumption (Merton, 1973; Breeden, 1979).

²See e.g. Cornell and Reinganum (1981), Hodrick and Srivastava (1987), Chang and Chang (1990), Polakoff and Grier (1991).

³In a previous paper entitled "Estimating a Latent Risk Premium in Exchange Rate Futures" we took a different approach and derived a methodology to correct the bias in the Fama regression caused by the existence of a latent risk premium. This allowed us to test whether the unbiased Fama coefficient is actually one and therefore consistent with the EH.

Against this background, we consider excess equity market returns, non-durable and durable consumption growth as the potential common (risk) factors.⁴

As stressed by Burnside (2011) and Barroso and Santa-Clara (2015), one criticism of this risk-based explanation is that these general proxies of systematic risk are very often estimated to be uncorrelated with currency returns. A recent branch of the literature argues that the weak link between standard risk factors and currency excess returns can be overcome by considering a CAPM version that distinguishes between exposure to factor risk in periods of low returns (downside risk) and in periods of high returns (upside risk) (Lettau et al., 2014; Atanasov and Nitschka, 2014). We add to this discussion by arguing that asset maturity plays a critical role in whether or not excess currency returns reflect exposure to risk. In examining the validity of different types of CAPMs in connection with excess currency returns, the literature has so far concentrated only on selected maturities of usually one or three months. The novelty of our paper is that the use of futures exchange rates instead of forwards allows us to estimate the CAPM based model for a wide range of maturities. This allows us to shed light on why the results in the relevant literature are so heterogeneous and sometimes contradictory; see for instance the debate between Lustig and Verdelhan (2007, 2011) and Burnside (2011).

Our empirical results support the common hypothesis that the FFP is caused by an omitted variable bias due to the presence of a risk premium. We find that the (non-durable) consumption factor as well market risk help explaining currency returns, but only in the pre-crisis period and when asset maturity is longer than around three months. Considering that most studies that test the validity of a risk-based approach to excess currency returns focus on short maturities of one or three months, our results serve as an explanation for why this approach is so often rejected. Our findings suggest that these studies simply considered maturities too short to confirm the risk-based approach to currency returns.

The remainder of this paper proceeds as follows. Section 2 investigates the relationship between the spot return and the futures premium over the complete maturity spectrum ranging from two days up to one and a half years and for various time periods. Section 3 shows the estimation results of the CAPM to test, whether excess currency returns reflect a compensation for currency risk. Section 4 concludes. Some results and proofs are delegated to Appendices.

⁴Next to market risk and consumption growth risk, also other risk factors have been proposed, such as the high minus low (HML) carry factor (Lustig et al., 2011), the global currency volatility factor (Menkhoff et al., 2012), the FX correlation risk factor (Mueller et al., 2017) and the US dollar factor (Verdelhan, 2018). For reasons of space, we cannot examine the relevance of all these potential risk factors. However, market risk and consumption risk are the most frequently discussed risk factors in connection with excess currency earnings. By focusing on these, we also contribute to the debate between Lustig and Verdelhan (2007, 2011) and Burnside (2011).

2 The Expectations Hypothesis and Uncovered Interest Parity

Let s_t denote the log of the spot exchange rate between two countries at time t and f_{t-m}^t the log of the futures exchange rate at time $t - m$ with delivery at time t and maturity m . According to the expectations hypothesis (EH) f_{t-m}^t should be an efficient predictor for the spot exchange rate s_t . Since exchange rates are known to be close to non-stationarity, the EH is usually not examined by regressing s_t on f_{t-m}^t , but the lagged spot exchange rate is subtracted from both variables. To simplify the notation, each variable is indexed by a tuple (m, t) denoting m days before the delivery date t . We define the log spot return $y_{m,t} = s_{0,t} - s_{m,t}$ and the futures premium $x_{m,t} = f_{m,t}^t - s_{m,t}$. The standard EH test involves estimating the following regression:

$$y_{m,t} = \alpha_m + \delta_m x_{m,t} + \varepsilon_{m,t}. \quad (1)$$

Under the EH, $\alpha_m = 0$ and $\delta_m = 1$. We refer to specification (1) as the *Fama Regression*. The forward or futures premium puzzle (FFP) describes the phenomenon that the ‘Fama coefficient’ δ_m is very often estimated to be negative, which would suggest that if the futures premium indicates an expected appreciation of the domestic currency, the currency actually tends to depreciate, and vice versa.

Testing for the validity of the EH is closely related to testing whether the uncovered interest parity (UIP) condition holds. Let $i_{m,t}$ be the domestic m -period nominal interest rate and where $i_{m,t}^*$ is the corresponding foreign interest rate. The excess return of a domestic deposit held from period $t - m$ to t inclusive of currency returns on the foreign investment is defined as $r_{m,t} \equiv (i_{m,t} - i_{m,t}^*) - y_{m,t}$. Under the condition of UIP, there should be no excess returns on deposits in one country relative to another, so $r_{m,t}$ should be zero. Assuming that the covered interest parity is met (Akram et al., 2008), the futures premium corresponds to the interest rate differential between the two respective countries, $x_{m,t} = (i_{m,t} - i_{m,t}^*)$. Currency excess returns can therefore also be expressed as $r_{m,t} = x_{m,t} - y_{m,t}$, and we can reformulate regression (1) as follows:

$$r_{m,t} = \tilde{\alpha}_m + \tilde{\delta}_m x_{m,t} + \varepsilon_{m,t}, \quad (2)$$

where $\tilde{\alpha}_m = -\alpha_m$ and $\tilde{\delta}_m = 1 - \delta_m$. Under the EH and UIP, $\tilde{\alpha}_m = 0$ and $\tilde{\delta}_m = 0$ and excess returns should be zero. Thus, if $\tilde{\delta}_m \neq 0$, excess returns exist and are a function of the futures premium or, equivalently, of the interest rate differential between the two countries and thus predictable, which violates the EH.

A negative estimate of the Fama coefficient δ_m in equation (1) corresponds to a positive

estimate of the coefficient $\tilde{\delta}_m$ in the excess return equation (2). Thus, the often described FFP indicates that the country with the higher interest rate tends to have positive excess returns as its currency tends to appreciate. If the Fama coefficient is larger than the hypothesized value ($\delta_m > 1$ or $\tilde{\delta}_m < 0$), the country with the lower interest rate tends to have positive excess returns, since its currency appreciates by more than predicted by UIP.

2.1 Data

Our empirical work uses daily closing spot exchange rates and three-months exchange rate futures contracts with delivery dates at the third Wednesday in March, June, September, and December of each year. We examine the behavior of exchange rates for the United States relative to all countries for which currency futures have been traded at the Chicago Merchantile Exchange. These are nine developed countries, i.e. Australia, Canada, Germany, Japan, New Zealand, Norway, Sweden, Switzerland, the United Kingdom, and six emerging market economies, i.e. Brazil, Czech Republic, Hungary, Mexico, Poland and South Africa.⁵ For the estimations, we always consider the United States as the foreign country, and consider the other economies as the domestic country. Exchange rates are quoted in terms of the domestic currency price of one USD. Data sources are Bloomberg and Datastream.

Table 4 in the appendix gives an overview about the expiry month of the first traded futures contract of each individual currency contained in our sample. Only five bilateral currencies futures of our sample have been traded since the mid 70's. These are the Deutsche mark, Canadian dollar, Swiss franc, Pound sterling, and Japanese yen. Trade of the remaining currency futures contracts have started later in the 90s or mid 2000s. The maximum length of time to maturity m at which futures contracts have been traded, do not differ much between the individual currencies and develop very homogeneously over time. Figure 1 in the appendix shows, for simplicity's sake, the average of the maximum maturity across all currencies in our sample. As one can see, available maturities of the considered futures contracts have increased over time. From the mid-1970s to 2002, futures contracts were traded with an average maximum maturity ranging between nine and twelve months (or 200 and 280 business days). Between 2002 and 2014, the average of the maximum length of time to maturity has increased to around 390 working days, which is about one and a half years. From 2015 onwards, futures contracts were offered for the major currencies, i.e. the German mark, Canadian dollar, Swiss franc, Pound sterling and Japanese yen, with a continuously

⁵After the introduction of the Euro in 1999, we use for Germany Euro/USD rates instead of DM/USD rates. We have not considered futures data for the South Korean won, the Israeli shekel and the Turkish lira as trading did not start until 2006 or 2012, respectively. In addition, we have removed the Russian rouble from our sample due to the occurrence of several currency crises in the last two decades. Since the USD/Euro exchange rate in our sample is already covered by Germany, we have not included the data on French Franc futures.

rising maturity of up to five years (or 1305 working days).

2.2 Estimation Results

2.2.1 The Fama regression across the maturity spectrum

To examine the Expectations Hypothesis for a sufficiently long time period, we first base our estimates of equation (1) on a sub-sample consisting of the German mark, Canadian dollar, Swiss franc, pound sterling and Japanese yen against USD futures contracts. This set of five currencies is particularly interesting for examining the FFP because of their large market depth. For each currency, we focus on a total of 161 futures contracts with settlement days between March 1979 and December 2018, thus $t = 1, \dots, 161$. We chose this starting date, since it was not until 1976 that these major countries made a firm transition to a modern flexible exchange rate regime ratified by the Interim Committee of the International Monetary Fund. Moreover, for the earlier Japanese yen futures contracts the maximum length of maturity was rather volatile.

We begin by investigating whether the relationship between the log spot return $y_{m,t}$ and the futures premium $x_{m,t}$ depends on the maturity of the futures contract, m . For this we estimate for each currency the Fama regression covering all 161 futures contracts but allowing for separate slope coefficients for futures prices with different maturities.⁶ We consider futures prices with maturities ranging from two business days to the longest maturity that is available for all contracts falling within the observed period (M). This ensures that all M regressions cover the entire period under consideration. For the DM/Euro, Japanese yen and Pound sterling futures rates the longest available maturity for all contracts is 175 business days (eight months), for the Canadian dollar and Swiss franc it is 199 business days (nine months).

One way to estimate equation (1) is to apply an OLS estimator separately for every maturity $m \in \{2, \dots, M\}$.⁷ In this case we would end up with $M - 1$ individual regressions each based on 161 observations for each currency. However, since futures and spot prices are correlated across maturities, these regressions would not be independent of each other and the error vectors $\varepsilon_{m,t}$ would be correlated across m . Taking this dependence into account leads to more efficient estimates of the standard errors. To do that, we treat equation (1) as a panel with maturity length m as the cross-sectional and the maturity dates t of the individual contracts as the time dimension. To estimate the panel we apply the Beck and Kratz (1995) OLS estimator with panel-corrected standard errors. The estimator corrects

⁶We have also considered a pooled regression covering the data for all five currencies together, but our estimation results for the individual currencies suggest that the estimated coefficients vary considerably from currency to currency. Therefore, pooling appears not to be a good idea.

⁷Dickey-Fuller tests show that the futures premium and the exchange rate returns are stationary.

for heteroskedasticity, correlation across maturities and, if necessary, serial correlation.

For all five currencies and maturity horizons, we find that the estimated intercepts α_m are small and not significantly different from zero. Figure 2 in the Appendix plots the estimates for the slope coefficients δ_m together with their 95 percent confidence intervals against the maturity length in days, m . We find for maturities shorter than about a month that the slope coefficients are positive and very often not significantly different from the hypothesized value of one. Thus, we cannot reject the validity of the EH at the short end of the maturity spectrum. However, except for the Canadian Dollar futures contracts, the estimated slope coefficients eventually turn negative at longer horizons. For Euro/DM, Pound sterling and Swiss franc futures contracts this reversal is observed for maturities of longer than one month; for Japanese Yen futures contracts this only occurs at maturities longer than about three months (66 business days). For futures contracts denominated in Japanese yen, pound sterling and Swiss francs, the slope coefficients for maturities of more than 90 working days are, with a few exceptions, significantly negative. This is in line with the often described FFP, indicating that countries with the higher interest rate tend to have positive excess returns.

Table 1 summarizes the results of various hypothesis tests on the Fama coefficients and confirms the graphical examination. For all five currencies, we must reject the EH of $\delta_m = 1$ for the majority of maturities. The acceptance probability converges to zero with the maturity. In contrast, we cannot reject the null hypothesis of $\delta_m = -1$ for DM/Euro and Pound sterling futures contracts for all maturities over three months, for the Japanese yen this is the case for 87% of maturities and for the Swiss franc for 45%.

It could be that the negative coefficients are an artifact due to a winding down of trading activity as the expiration day of a contract draws closer. To assure that this is not the case, we analyze the trading volume, the average daily return and the annualized volatility of the futures prices with respect to maturity. We find that the liquidity of futures markets seems to be high also for futures contracts close to expiry. For very short maturities of less than five days, the trading volume is somewhat lower, but it increases steadily in maturity and reaches its maximum seven days prior to expiry. For maturities up to 77 days the liquidity stays high. However, thereafter the trading volume decreases rapidly, which confirms the usual finding that investors tend to invest mostly in the nearest-maturity futures contract. However, the pattern of the trading volume seems to have no significant effect on the daily returns nor on the volatility of futures prices.⁸

⁸We have also repeated all our estimations dropping all observations for maturities longer than 77 days and all our results were unaffected. Figures and estimation results are available on request.

Table 1: Hypothesis tests on Fama coefficients - 1979-2018

	H_0	$\delta_m = 0$	$\delta_m = -1$	$\delta_m = 1$
DM/Euro	all maturities	97%	90%	26%
	$m \geq 66$	100%	100%	3%
	$m \geq 135$	100%	100%	0%
Canadian dollar	all maturities	92%	2%	4%
	$m \geq 66$	55%	1%	14%
	$m \geq 135$	61%	1%	12%
Swiss franc	all maturities	4%	20%	0%
	$m \geq 66$	2%	47%	0%
	$m \geq 135$	3%	45%	0%
Japanese yen	all maturities	59%	59%	37%
	$m \geq 66$	58%	87%	13%
	$m \geq 135$	15%	100%	0%
Pound sterling	all maturities	55%	86%	22%
	$m \geq 66$	35%	100%	0%
	$m \geq 135$	18%	100%	0%

Notes: This table shows the ratio of regressions, for which the null hypotheses $\delta_m = 0$, $\delta_m = -1$, and $\delta_m = 1$ could not be rejected at the 5% significance level.

2.2.2 The Fama regression over time

In the following, we analyse the occurrence of the FFP in more detail over time. Thornton (2007) shows for forward data that the appearance of the FFP depends significantly on the choice of the sample period. This result is also recently confirmed by Kim et al. (2017) who analyse the related UIP condition for fourteen major US trading partners for various time periods and policy regimes. On the basis of this evidence, we employ a supremum Wald test (Andrews, 1993) to detect a possible structural break in the relationship between exchange rate innovations, $y_{m,t}$, and the futures premium, $x_{m,t}$, at an unknown date for all M maturities. For this test, one needs to define a trimming parameter which specifies how far into the sample (as a percentage of the full sample size) one starts looking for a break, with a symmetric fraction of the sample left after the latest break evaluated. We use a 15 percent trimming, i.e. we look for a structural break in the time period that includes all futures contracts that settle between June 1985 and March 2013.⁹

For the Pound sterling and the Canadian dollar, we can reject the null hypothesis of no structural break in 151 of 175 regressions and 122 of 199 regressions, respectively. For DM/Euro futures prices, Wald test statistics indicate the presence of a statistically significant structural break in 39 of 175 regressions. The signs of a structural break are weaker for futures contracts in Swiss francs and Japanese yen. Here the Wald test statistics are only significant for 14 out of 199 and 27 out of 175 regressions at the 90 percent significance level.

⁹As a robustness test, we also used a 10 percent trimming. The estimation results did not differ substantially.

Figure 3 and Figure 4 in the appendix plot the Wald statistics of the null hypothesis of no structural break over the period considered for selected maturities of one, three, six and eight months. One can see that the probability of a structural break in δ_m increases in the maturity of futures rates. For maturities longer than three months, we observe for all five currencies a peak in the break statistics in the period around the major financial crisis of 2007-10. With the exception of the Swiss franc and the Japanese yen, the test statistics are significant at least at the 90% significance level. It is worth noting that we do not confirm the result of Kim et al. (2017), who found evidence of a structural break immediately after the Volcker era of 1987. Only for Pound sterling futures contracts, we observe a second significant breakpoint around 1990, coinciding with the period when the UK joined the European Exchange Rate Mechanism (ERM) and experienced a short period of currency crisis two years later when it was forced to leave the exchange rate system (Black Wednesday). These results suggest that the relationship between exchange rate innovations and the futures premium puzzle changes primarily during turbulent periods.

In view of the indications of a structural break in the Fama coefficient δ_m after the outbreak of the global financial crisis, we have divided our sample into two sub-samples: The first sub-sample covers the pre-crisis period, which includes all futures contracts that mature between March 1979 and June 2007. The estimation results are shown in Figure 5. The second sample covers the post-crisis period, including all futures contracts that settle between September 2007 and December 2018. Since futures contracts are available for more USD currency pairs in the post-crisis period (see table 4), we extended our analysis to fifteen instead of only five currencies for the second sub-sample. Moreover, the longest maturity at which futures contracts have been traded in the post-crisis period has also increased, which allows us to extend the maturity spectrum for which we estimate the Fama coefficients δ_m up to one and a half years (385 business days). Figure 6 shows the results.

We confirm that the occurrence of the FFP significantly depends on the choice of the sample period. When we focus on the pre-crisis sample covering futures contracts expiring between March 1979 to June 2007, we find for all five currencies – thus, this time also for the Canada dollar – a negative relationship between the slope coefficient of the Fama regression and the time to maturity of the futures contract m . The slope coefficients continuously decrease from positive values close to one for short maturities to negative values fluctuating between 0 and -2.5 for longer maturities. As shown in table 2, we have to reject the EH for almost all maturities over three months, which confirms excess returns on currency markets. For medium to long maturities, we cannot reject in any regression that the Fama coefficient is equal to minus one. These findings also confirm the FFP and indicate that the country with the higher interest rate tends to have positive excess returns because its currency tends to appreciate in contrast to the prediction of UIP.

Table 2: Hypothesis tests on Fama coefficients - 1979-2007

	H_0	$\delta_m = 0$	$\delta_m = -1$	$\delta_m = 1$
DM/Euro	all maturities	77%	94%	20%
	$m \geq 66$	69%	100%	1%
	$m \geq 135$	51%	100%	0%
Canadian dollar	all maturities	98%	86%	18%
	$m \geq 66$	100%	97%	0%
	$m \geq 135$	100%	97%	0%
Swiss franc	all maturities	66%	77%	19%
	$m \geq 66$	57%	95%	1%
	$m \geq 135$	37%	100%	0%
Japanese Yen	all maturities	41%	63%	28%
	$m \geq 66$	24%	80%	6%
	$m \geq 135$	0%	58%	0%
Pound Sterling	all maturities	37%	87%	17%
	$m \geq 66$	8%	97%	0%
	$m \geq 135$	0%	98%	0%

Notes: This table shows the ratio of regressions, for which the null hypotheses $\delta_m = 0$, $\delta_m = -1$, and $\delta_m = 1$ could not be rejected at the 5% significance level.

However, when we repeat the estimates for the later sub-sample, we find that for all currencies except the Brazilian real, the Mexican peso and the South African rand, the slope coefficients remain positive over the entire maturity horizon. For DM/Euro, Swiss franc, Japanese yen, Australian dollar, Czech koruna, Brazilian real, Hungarian forint and Polish zloty futures contracts, we cannot reject the EH of a Fama coefficient of one for the majority of maturities considered, as summarized in Table 3. Thus, excess returns are not observed anymore for these currencies. In contrast to the pre-crisis period, however, we estimate for futures on Pounds sterling, Canadian dollars and Japanese yen a *positive* trend between the δ_m and the maturity horizon of the futures contracts. As a result, the EH holds for these currencies only for maturities of less than half a year (135 working days). For longer maturities, δ_m is very often significantly larger than one. So we reject for these three currency the EH for longer maturities, but this time the deviations go into the opposite direction than in the pre-crisis period. The country with the lower interest rate tends to have now positive excess returns. Our results are essentially consistent with the outcome of Kim et al. (2017). Analysing 3-months foreign currency excess returns, they find that the UIP fails to hold during the Volcker era in the 1980s but tends to hold looking at the post Volcker era from 1987 to 2007. The only difference is that, according to our findings, the break of the slope

Table 3: Hypothesis tests on Fama coefficients - 2007-2018

	H_0	$\delta_m = 0$	$\delta_m = -1$	$\delta_m = 1$
DM/Euro	all maturities	47%	25%	80%
	$m \geq 66$	36%	14%	75%
	$m \geq 135$	20%	2%	66%
Canadian dollar	all maturities	9%	6%	14%
	$m \geq 66$	15%	11%	22%
	$m \geq 135$	4%	2%	8%
Swiss franc	all maturities	73%	36%	76%
	$m \geq 66$	96%	50%	99%
	$m \geq 135$	96%	43%	100%
Japanese Yen	all maturities	29%	10%	71%
	$m \geq 66$	23%	8%	66%
	$m \geq 135$	12%	1%	58%
Pound Sterling	all maturities	2%	1%	4%
	$m \geq 66$	5%	3%	10%
	$m \geq 135$	0%	0%	1%
Australian dollar	all maturities	70%	53%	76%
	$m \geq 66$	92%	70%	99%
	$m \geq 135$	92%	68%	100%
New Zealand dollar	all maturities	21%	12%	36%
	$m \geq 66$	9%	5%	22%
	$m \geq 135$	1%	0%	14%
South African rand	all maturities	73%	79%	63%
	$m \geq 66$	67%	80%	53%
	$m \geq 135$	49%	69%	33%
Czech koruna	all maturities	47%	29%	69%
	$m \geq 66$	40%	22%	63%
	$m \geq 135$	17%	3%	45%
Brazilian real	all maturities	95%	86%	99%
	$m \geq 66$	99%	95%	100%
	$m \geq 135$	100%	99%	100%
Hungarian forint	all maturities	99%	65%	98%
	$m \geq 66$	100%	60%	99%
	$m \geq 135$	100%	41%	100%
Mexican peso	all maturities	56%	78%	37%
	$m \geq 66$	50%	76%	27%
	$m \geq 135$	38%	70%	16%
Polish zloty	all maturities	44%	21%	65%
	$m \geq 66$	38%	19%	59%
	$m \geq 135$	22%	5%	48%
Swedish krona	all maturities	92%	46%	98%

	$m \geq 66$	92%	37%	100%
	$m \geq 135$	92%	26%	100%
Norwegian krona	all maturities	46%	18%	77%
	$m \geq 66$	41%	13%	72%
	$m \geq 135$	33%	7%	67%

Notes: This table shows the ratio of regressions, for which the null hypotheses $\delta_m = 0$, $\delta_m = -1$, and $\delta_m = 1$ could not be rejected at the 5% significance level.

coefficient occurs much later with the outbreak of the global financial crisis.¹⁰

In summary, the existence of currency excess returns and the occurrence of the FFP is not set in stone. They depend both on the maturity of the assets under consideration and on the choice of sampling period. The FFP appears to be a pre-crisis phenomenon for most currencies and disappears afterwards. Since the onset of the global crisis, we cannot reject the validity of the EH and the absence of currency excess returns for most currencies and maturities. In the case of significant deviations from the EH, this time they tend to go into the opposite direction than usually described in the earlier literature: The currency of the country with the relatively lower interest rate tends to appreciate much more than the futures premium indicates.

Since Fama (1984) a common explanation for the failure of the EH/UIP is that it is driven by a time-varying risk premium that investors demand for foreign currency denominated investments.¹¹ The negative Fama coefficient estimated for medium to long maturities for the majority of currencies for the pre-crisis sample would indicate that this risk premium and the expected change in the exchange rate have a negative covariance and that this covariance is of a magnitude larger than the expected exchange rate volatility. A Fama coefficient larger than the hypothetical value of one that we estimate for three of the five currencies for longer maturities in the post-crisis period indicates that the volatility of the risk premium is in these cases greater than the volatility of the expected exchange rate changes.¹²

¹⁰Although not indicated by the tests for a structural break, we have, following Kim et al. (2017), estimated the Fama regression also separately for the post-Volcker period (1987 to 2007). With the exception of the futures on Pounds sterling, we also find negative slope coefficients in the post-Volcker period, which decrease in maturity. Thus we do not confirm that the occurrence of the FFP is a particular phenomenon of the Volcker era. These regressions results are available from the authors on request.

¹¹See also Hsieh (1984); Hodrick and Srivastava (1987); Sarno et al. (2012); Lustig et al. (2014).

¹²A detailed derivation of these conclusions are found in Fama (1984).

3 Excess Returns and Risk Premia

In this section we test whether the observed excess returns on futures contracts indeed reflect a fair compensation for currency risk. The capital asset pricing model (CAPM) of Sharpe (1964), Lintner (1965) and Black (1972) suggests that the expected excess returns should equal a risk premium times the amount of risk of each asset. As potential common risk factors we follow Jensen (1972), Merton (1973) and Breeden (1979) and consider excess stock market returns, non-durable consumption growth, and durable consumption growth. In this way we contribute to the debate between Lustig and Verdelhan (2007, 2011) and Burnside (2011).

In examining the validity of different types of CAPM based models in connection with excess currency returns, the literature has so far concentrated on selected maturities of usually one or three months. The novelty of our paper is that the use of futures exchange rates instead of forwards allows us to estimate the CAPM based model for a wide range of maturities. This allows us to analyze, whether asset maturity plays a critical role in whether or not excess currency returns reflect exposure to risk.

3.1 Methodology

We simplify in the following the notation by dropping the maturity index, while adding an index j for the currency with $j = 1, \dots, J$. Assume that the currency excess returns r_{jt} from 2 are governed by a single factor model:

$$r_{jt} = \xi_j + \beta_j f_t + \nu_{jt}, \quad j = 1, \dots, J, \quad t = 1, \dots, T, \quad (3)$$

where f_t is the realization of a common (risk) factor, ξ_j is a constant and ν_{jt} is a random error term. The β_j measures the sensitivity of the excess return of the currency j futures contract to variation in the common factor and thus serves as the measure of riskiness of the futures contract.

Instead of estimating equation (3) for all currencies separately by OLS, we estimate the factor betas jointly with the Generalized Method of Moments (GMM), which is robust to conditional heteroscedasticity, cross-sectional as well as serial correlation in the return residuals and the factor. The moment restrictions are:

$$\mathbb{E} \begin{bmatrix} r_{jt} - \xi_j - \beta_j f_t \\ (r_{jt} - \xi_j - \beta_j f_t) f_t \end{bmatrix} = 0, \quad (4)$$

Taking into account that the time span covered differs between the individual currencies (see table 4), we do not restrict the estimation sample to be the same for all equations. We

use a robust weighting matrix with the identity as the initial one.

The asset pricing hypothesis is that currency returns are a function of the sensitivities to the risk factor – the factor beta β_j – and the price of risk γ_1 :

$$E[r_t] = \gamma_0 + \beta' \gamma_1, \quad (5)$$

where $E[r_t]$ is the J -vector of expected excess returns, β is the J -vector of the estimated betas of equation (4). The intercept γ_0 can be interpreted as the zero-beta return and allows for a common over- or underpricing in the cross section of returns.¹³

The primary interest in the literature is to test, whether a specific risk factor is priced, thus, whether the null hypothesis $H_0 : \gamma_1 = 0$ holds. Fama and MacBeth (1973) have proposed a two-step regression approach in which the estimated β_j 's of equation (4) are used as regressors in the cross-sectional regression (5) to estimate the risk premium γ_1 . However, as is criticized by Burnside (2011), this approach neglects the fact that first-pass betas are estimated with uncertainty. Failure to account for this uncertainty results in biased standard errors in the γ_1 estimate. One way to avoiding this error-in-variable problem is to estimate the risk premium γ_1 directly by GMM.¹⁴ Note that equation (5) can be written as:

$$E[r_t] = \gamma_0 + \gamma_1 \frac{\text{cov}(r_t, f_t)}{\sigma^2}, \quad (6)$$

where σ^2 is the factor variance. We follow Harvey and Kirby (1995) and Shanken and Zhou (2007) and use the following moment conditions:

$$\mathbb{E} \begin{bmatrix} r_t - \mu_r \\ f_t - \mu_f \\ (f_t - \mu_f)^2 - \sigma^2 \\ r_t - \gamma_0 - \gamma_1 \frac{(r_t - \mu_r)(f_t - \mu_f)}{\sigma^2} \end{bmatrix} = 0, \quad (7)$$

where μ_r and μ_f are the population means of the excess returns and the factor. Thus, because we use multiple currencies we use for the estimation $2(J + 1)$ moment conditions across these currencies. We use again robust weighting matrices for the estimates, with the identity matrix selected as the initial matrix.

¹³Since our explanatory variable is the excess currency return and not - as is often the case in CAPM literature - an excess asset return above the risk-free interest rate, the inclusion of an intercept makes economic and econometric sense.

¹⁴Another solution is the correction of the standard errors, as suggested by Shanken (1992). Jagannathan and Wang (1998) point out that in case of heteroskedasticity, Shanken's correction is inappropriate and that more general GMM errors are preferred. In addition, Shanken and Zhou (2007) perform a simulation analysis of various possible estimators and find that this GMM estimator performs best in terms of the mean square error (RMSE). Nevertheless, we have estimated our model as a robustness test with Shanken-corrected standard errors. The results are comparable to those shown in detail in this paper.

Our contribution complements the literature by estimating the CAPM model for a wide range of maturities. We estimate the models (4) and (7) for all maturities between one day and eight months ($m = 1, \dots, 174$), when we consider the complete time horizon from 1979 to 2018, and between one day and one year ($m = 1, \dots, 260$), when we limit the estimation to the post-crisis period.¹⁵ We refrain from estimating the model separately for the pre-crisis period, as trading in futures for six of the 15 currencies only began in 2004 or 2007, respectively. We consider excess stock market returns, non-durable consumption growth, and durable consumption growth as common (risk) factors. Data on daily excess stock market returns are provided by Fama and French Research Factor file, from which we calculate m -period returns.¹⁶ US per capita durable and non-durable real consumption are used to calculate consumption risk. The consumption data were downloaded from the website of the Federal Reserve Bank of St. Louis. The shortest available frequency is monthly. We therefore attribute the one-month consumption growth rate to all excess currency returns with a time to maturity of less than one month, the two-month consumption growth rate to excess currency returns with a time to maturity between one and two months, and so on. All factors are calculated as deviations from the mean value, taking into account that the distribution of factor values is maturity specific.

3.2 Results

Figures 7 to 9 show the factor betas of each currency in relation to the futures contracts' maturity m together with their 95% significance band when estimated over the entire sample including all futures contracts with expiration dates between March 1979 and December 2018.

The sensitivity of the euro, Swiss franc, Japanese yen and pound sterling futures contracts to excess equity market returns, i.e. the traditional market betas, proves with only a few exceptions to be virtually zero and insignificant across the considered maturity spectrum (see Figure 7). Hence, these currencies turn out to be immune to stock market movements and could therefore serve as a 'safe haven'. For futures contracts in Australian dollar, Canadian dollar, New Zealand dollar and South African rand, we find consistently positive and mostly statistically significant market betas for all considered maturities. This indicates that these currencies have significantly negative returns when equity markets are falling and are therefore considered 'risky'. We also confirm a predominantly positive market beta – and thus a risky status – for the remaining futures exchange contracts, i.e. Brazilian real, Czech koruna, Hungarian forint, Mexican peso, Norwegian krone, Polish zloty and Swedish krone.

¹⁵We limit the estimates to maturities of up to 174 and 260 working days, respectively, as we would shorten the observation period if longer maturities were chosen. The reason for this is that earlier futures contracts were not traded for very long maturities.

¹⁶<http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/>

However, for this group of currencies the size and significance of the market betas depends on the maturity under consideration. It appears that the sensitivity to market risk increases with the maturity of the futures contract. For short maturities of less than two to three months (50 working days), the beta estimate is mostly insignificant and small in magnitude. For longer maturities, the beta is consistently positive and usually statistically significant.

When comparing the 95 % confidence bands of beta estimates between currencies, we conclude that there are significant differences in the sensitivity of individual currencies to equity market risk. Market betas for emerging markets are proving to be significantly larger than those for developed markets, underlining the greater risk associated with the former due to hot money flows. However, this spread in the betas becomes more prominent for maturities longer than about two months.

Moreover, we find that currency excess returns also reflect consumption risk. However, only non-durable consumption seems to be of importance and not durable consumption. With few exceptions, the durable consumption betas of all currencies are statistically insignificant and hover around zero across the entire maturity spectrum (Figure 9). In contrast, we estimate that, with the exception of futures contracts in Japanese yen, the sensitivity of currency returns to non-durable consumption increases with maturity (Figure 8). While the non-durable consumption betas are usually insignificant for short maturities, these are clearly positive for medium to long maturities, which indicates significant negative returns when non-durable consumption is falling. In addition, the estimated consumption betas for emerging market futures contracts are estimated to be significantly higher than for futures contracts in the major currencies DM/Euro, Pound Sterling, Canadian Dollar, Swiss Franc and Japanese Yen. These currencies are therefore considered ‘riskier’ and therefore pay a higher excess return.

Figure 10 shows the result of GMM estimates of the factor risk premium γ_1 and Figure 11 the corresponding model fit measured by the R-square. If we focus on excess equity market returns as our risk factor, we find that the estimate of the market risk premium increases monotonically over the maturity of the futures contracts. For short maturities of less than 50 business days, γ_1 is close to zero and insignificant. For maturities of more than three months, the market risk premia are, with few exceptions, significant at the 95% level and have the correct sign. These rise from 0.01 for a maturity of three months to 0.02 for the longest maturity considered, 174 working days.

As Lewellen et al. (2010) point out, in order to make a correct judgment about an asset pricing model, we need to consider not only the statistical significance of the risk premium, but also its magnitude and economic significance. In a regression of the excess stock market return to itself, the β coefficient is one. For this reason, the market risk premium γ_1 should be equal to the average excess US stock market return over a maturity range of m days. When

we annualize the significant estimates of the market risk premium γ_1 , the returns turn out to be very monotonous over the entire maturity spectrum, ranging between 3% - 10% p.a. with an average of 5% p.a. These are reasonable values given the historical long-term average US market excess returns of 8% according to the data on excess stock market returns provided by Fama and French Research Factor file. The constant γ_0 proves to be economically small for all maturities ranging between -0.007 and 0.001 and is insignificant in more than half of the 174 regressions. The model fit varies considerably across the maturity spectrum without showing a specific pattern. We find that market risk explains between 0% and 35% of the cross-sectional variation in currency returns. The average R-square over all 174 estimated models is 12%.

If we focus on durable consumption growth as our risk factor, we find that not only are the consumption betas insignificant, as shown above, but also the constant terms γ_0 and the risk premia γ_1 are highly insignificant over the entire maturity spectrum considered. Therefore, we conclude that we reject the durable consumption CAPM across the entire maturity spectrum. Consumption growth of durable goods does not appear to be volatile enough to measure the consumption beta accurately, and the consumption beta cannot take into account the cross-sectional spread of foreign exchange earnings.

A different picture emerges when we look at the growth in non-durable consumption. In this case γ_1 increases monotonically with the maturity of the futures contracts and is usually significant. For short maturities of less than 50 working days, the risk premium is negative and therefore has the wrong sign. However, this is also the maturity range over which the consumption betas for all currencies are considered insignificant. Since the contribution of the factor to the vector of model-predicted expected returns is $\beta^j \gamma_1$, this implies that for futures contracts with maturities shorter than around two and a half months one cannot reject the null that the non-durable consumption risk premium contributes little to the model-predicted expected currency returns.

In contrast, for maturities of more than 50 working days the estimated factor risk premia are highly significant and positive, indicating higher risk premia for currencies whose yields are developing positively with growth in non-durable consumption. Thus, we conclude that currency yields do reflect non-durable consumption risk for medium to longer maturities. Our estimates suggest that the average risk premium of a futures contract with a non-durable consumption growth beta of one yields an average risk premium that ranges between 0.15% and 1% p.a. with an overall average of 0.5% p.a. This is very much in line with the observed average non-durable consumption growth rate of 0.4 % p.a. over the observed time period. The constant γ_0 is with an average of -0.003 small in magnitude and significant at the level of 95% only in 20 out of the 174 considered maturities. The model fit varies considerably over the entire maturity spectrum (see Figure 11). Non-durable consumption growth risk

explains between 0% and 79% of the cross-sectional variation in currency returns. Over the entire maturity spectrum, the average R-square is 15%.

To summarize, our estimates suggest that the (non-durable) consumption factor as well market risk help pricing currency returns, but only when the asset maturity is longer than around three months. Considering that most studies that test the validity of a risk-based approach to excess currency returns focus on short securities maturities of one or three months, our results could explain why this approach is so often rejected. Our findings suggest that these studies simply considered maturities too short to confirm the risk-based approach to currency returns.

3.3 Robustness

In section 2 we have shown that the FFP appears to be a pre-crisis phenomenon and that for the period after 2007Q2 it seems to have disappeared for the majority of currencies. For only three of the fifteen currencies analyzed we still observe deviations from the EH, but this time in the opposite direction. One possible explanation is that market and consumption risk is less pronounced when we focus on the later sub-sample and that the significance of the risk premia observed across the entire data sample is mainly determined by the pre-crisis period. We therefore repeat our estimates of equation (4) and (7) focusing only on excess currency returns of futures contracts expiring between September 2007 and December 2018.

The Figures 12 to 15 show the estimated betas and risk premiums for the post-crisis period. We consider all futures prices with a maturity between one day and one year ($m = 1, \dots, 260$). While the market risk betas are still significant for most currencies, we find that, with few exceptions, estimates of market risk premiums are this time insignificant for all of the maturity horizons considered. Furthermore, the R -squared of our model does not exceed 10% for maturities longer than around 80 working days (Figure 16). We conclude that market risk has low explanatory power of currency excess returns in the post-crisis period.

Also for the post-crisis period we find little support for the idea that the excess foreign currency returns reflect durable consumption risk. The beta estimates are largely insignificant. Only at the end of the maturity spectrum with $m > 110$, we find that Pound sterling, Japanese yen, New Zealand dollar, and Norwegian krona excess currency returns turn out to be sensitive to durable consumption risk. However, as shown in Figure 15, the estimates of the durable consumption risk premium γ are insignificant and the model fit is virtually zero for almost all maturities longer than around 60 working days (see Figure 16).

Finally, we can no longer confirm with certainty that the excess currency earnings reflect the non-durable consumption risk in the post-crisis period. With the exception of the very short maturities of less than one month, the estimated betas are again positive and significant for all currencies except the Japanese yen (Figure 13). This suggests that the

excess returns on these currency futures contracts will fall as consumption in the non-durable goods sector declines. However, we find no clear evidence that this ‘riskiness’ is reflected in higher risk premiums. For maturities of more than 40 working days, this is the range where beta estimates are significant, but the γ_1 estimates hover around zero. They are mostly insignificant, but sometimes they are also significantly positive or negative.

We conclude that our estimate supports the hypothesis that a time-varying risk premium is responsible for the occurrence of FFP. In the pre-crisis period, excess currency returns seem to compensate investors for market risk and consumer risk, which is also the period in which the FFP is observed. Why this is no longer the case after the global financial crisis should be the subject of future research.

4 Conclusion

The forward premium puzzle (FFP) is the empirical observation that foreign exchange forward premia and the realized foreign exchange returns tend to be negatively correlated, which contradicts the Expectations Hypothesis (EH) and the related Uncovered Interest Parity Condition (UIP). In this paper we reconsider the FFP using futures instead of forward rates. We investigate the relation between the spot return and the futures premium for the US dollar exchange rates against the currencies of nine developed countries and six emerging markets economies between 1979Q1 and 2018Q4. Futures rates allow us to analyze the relationship at a daily basis with maturity horizons ranging from two days to several months. This yields estimates on a much finer grid than is currently available in the related literature.

Our first result is that not only the maturity horizon is important for the occurrence of the FFP, but also the observation period. So far as we know, we are the first, who obtain these results combined within a single study. For short maturities the Fama coefficient is generally positive, and the EH is not rejected by the data. For longer maturity horizons, however, the sign and also size of the slope coefficient depends on the time period covered. When focusing on the period prior the global financial crisis, the slope coefficient tends to become negative as the maturity horizon over which expectations are formed increases, which confirms the FFP. However, when we focus on the later period starting after the financial crisis, we observe that the FFP vanishes for all currencies. We cannot reject the EH of a Fama coefficient of one for the majority of maturities considered except for Pound sterling, Canadian dollar and Japanese yen futures contracts. For these contracts we observe a deviation from the EH for maturities of more than half a year, but this time upwards instead of downwards. These currencies tend to appreciate by more than is indicated by the futures premium. We conclude that the FFP seems to be a pre-crisis phenomenon.

Subsequently, we follow the common explanation that the FFP is caused by an omitted

variable bias due to the presence of a risk premium. Our contribution complements the literature by estimating the CAPM model for a wide range of maturities. We find that currency returns are associated with aggregate market risk and the risk of non-durable consumption, which supports a risk-based view of exchange rates. However, this result only applies to assets with a maturity of longer than about three months. Since most studies testing the validity of a risk-based approach to excess currency returns focus on short securities maturities of one or three months, our results provide a possible explanation for why the risk-based approach is so often rejected. When focusing on the post-crisis period only, we do not only find that the FFP has disappeared but we also reject that currency excess returns reflect a risk compensation.

Our results open new paths for future research. Given the proven empirical evidence, a complete theory of exchange rate and interest rate behavior needs to explain not only the FFP, but also why the magnitude and sign of the slope coefficient of the Fama regression depends on the maturity of the asset and the observed sample period.

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A Tables

Table 4: Overview about currency futures traded at the Chicago Merchantile Exchange

Currency	First traded contract
USD/German Mark(Euro)	September 1972
USD/Australian Dollar	March 1987
USD/Canadian Dollar	March 1973
USD/Swiss Franc	March 1973
USD/Sterling Pound	December 1975
USD/Czech Koruna	September 2004
USD/Brazilian Real	March 2007
USD/Hungarian Forint	September 2004
USD/Japanese Yen	March 1973
USD/S-African Rand	June 1997
USD/New Zealand Dollar	June 1997
USD/Mexican Peso	June 1995
USD/Polish Zloty	September 2004
USD/Swedish Krona	June 2004
USD/Norwegian Krona	June 2004

Trading for USD/Brazilian real futures contracts has started already in 1995, however, until 2007 trading was on an irregular basis.

B Figures

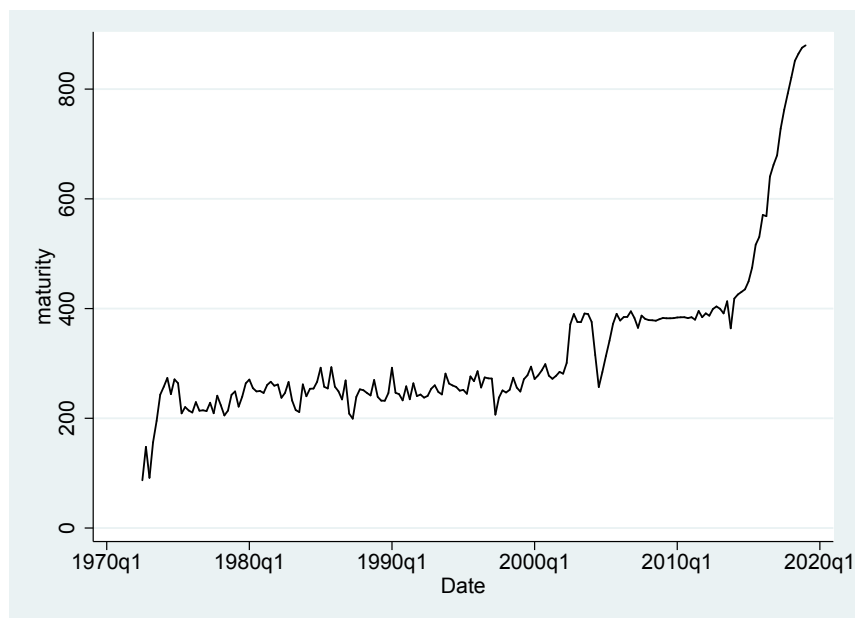
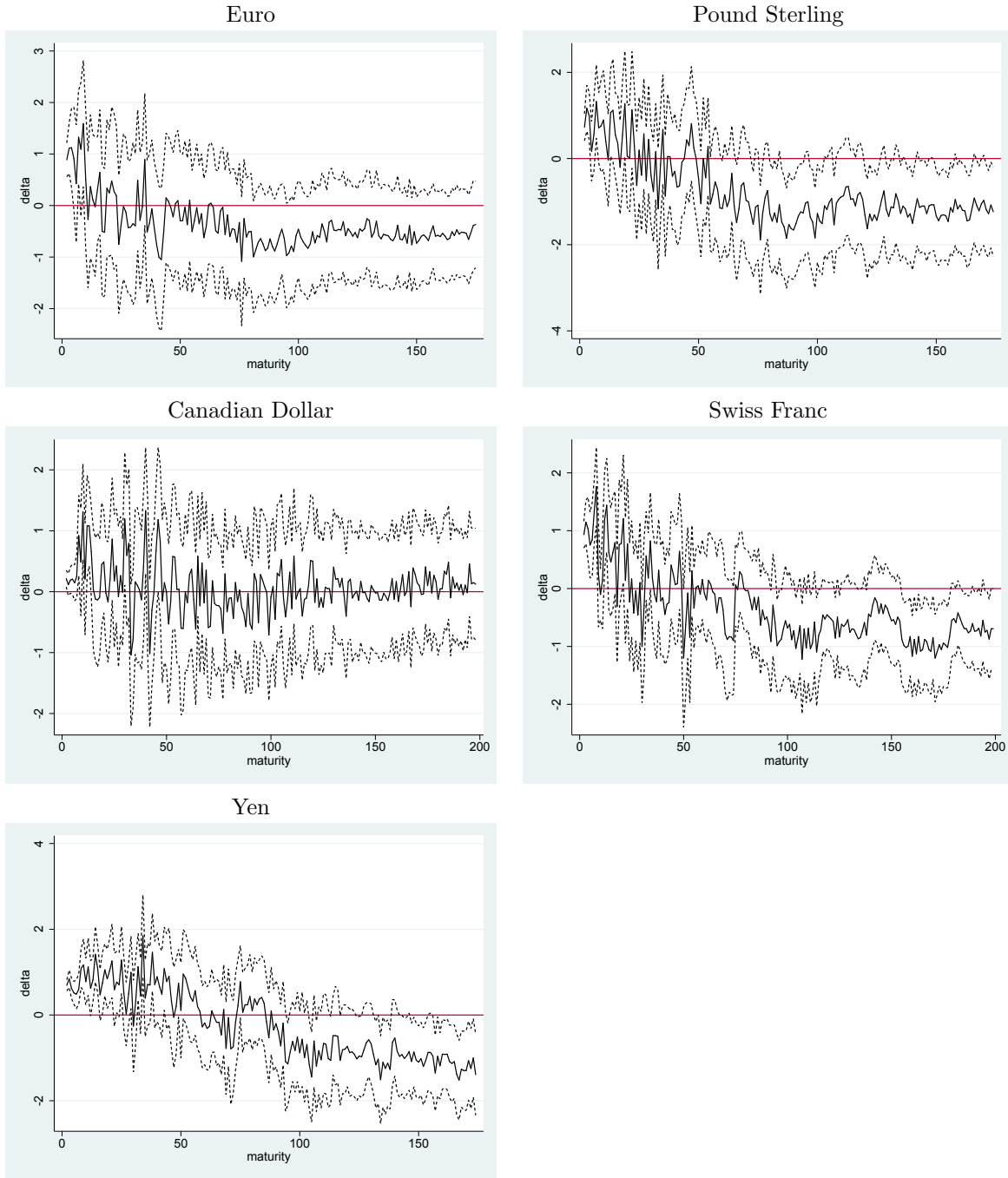
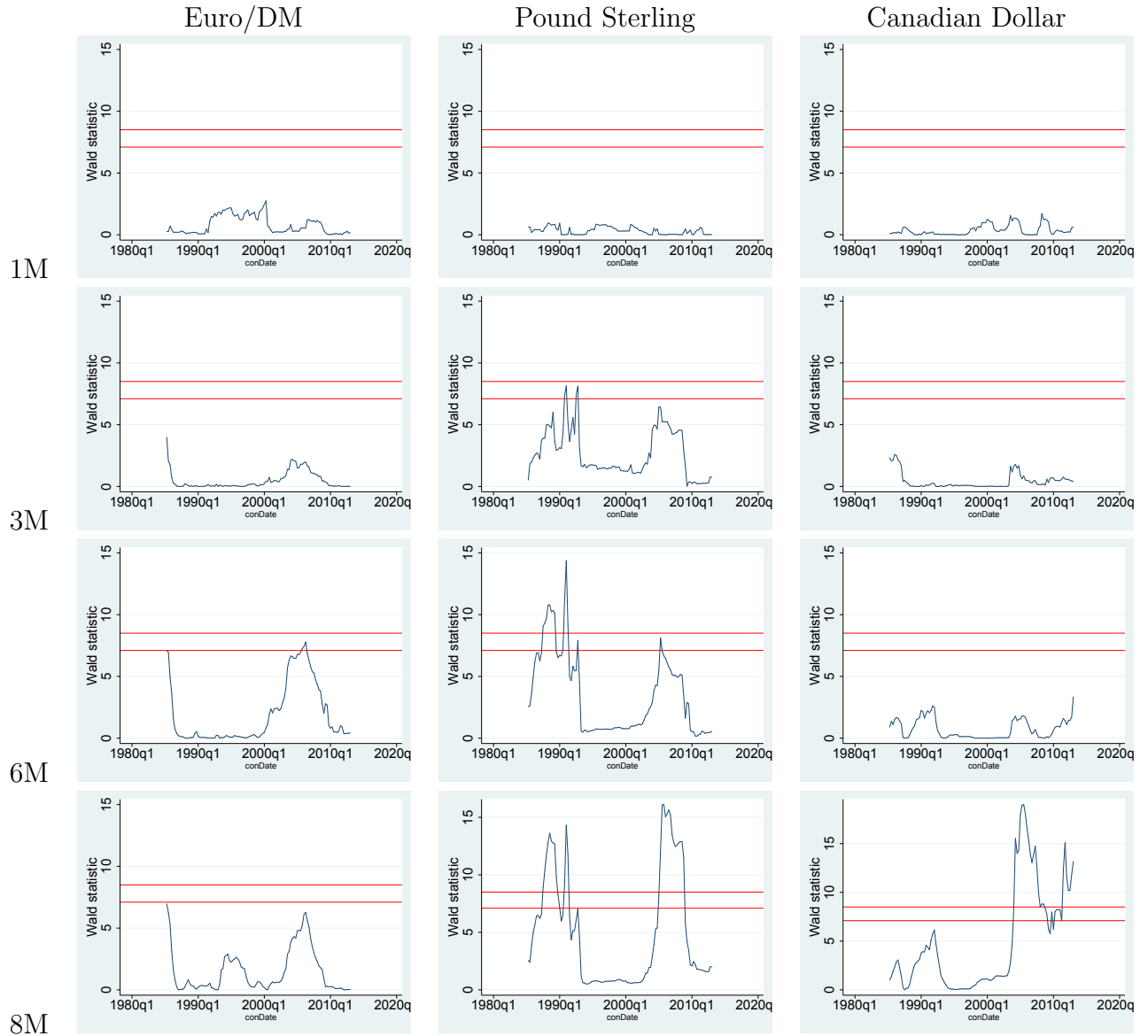


Figure 1: Average maximum maturity over time



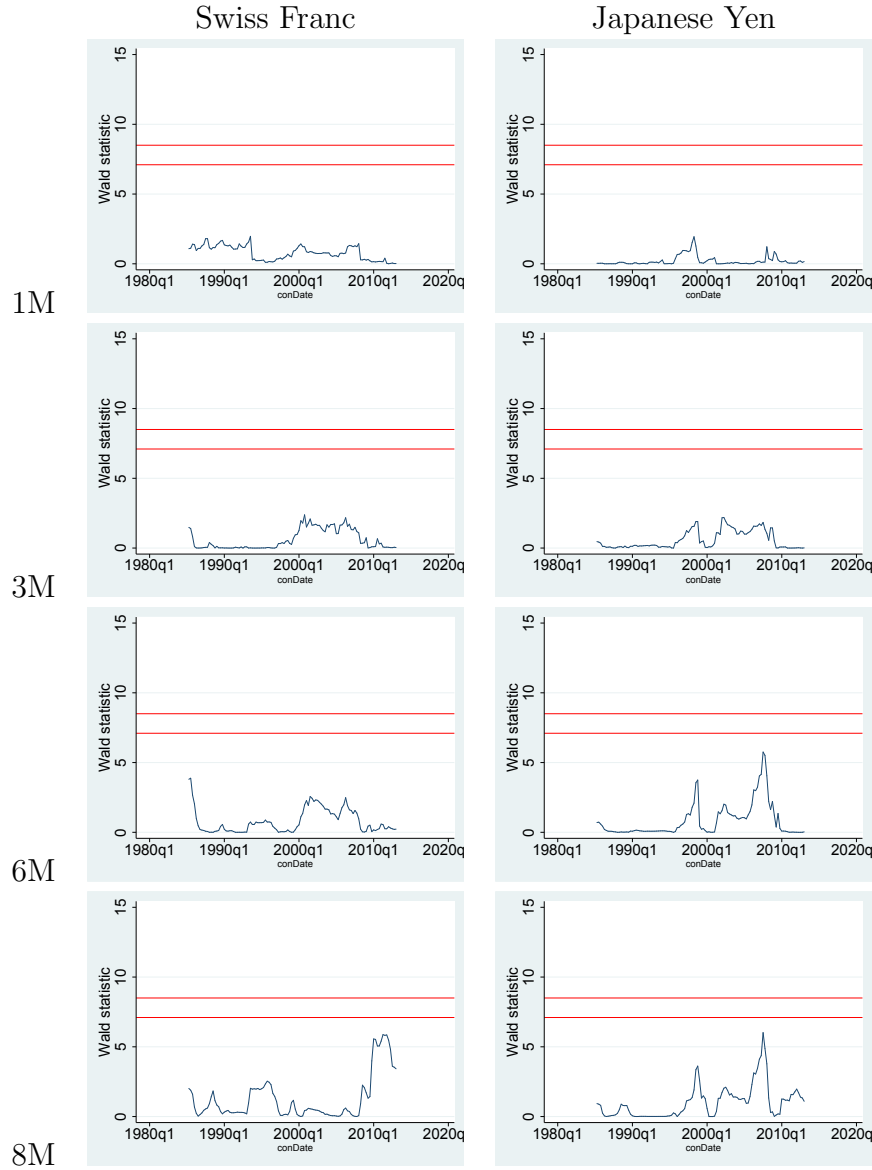
Notes: The upper and lower horizontal lines show the critical values for significance at the 95%, respectively.

Figure 2: Slope coefficients δ_m of the Fama regression: 1979 to 2018.



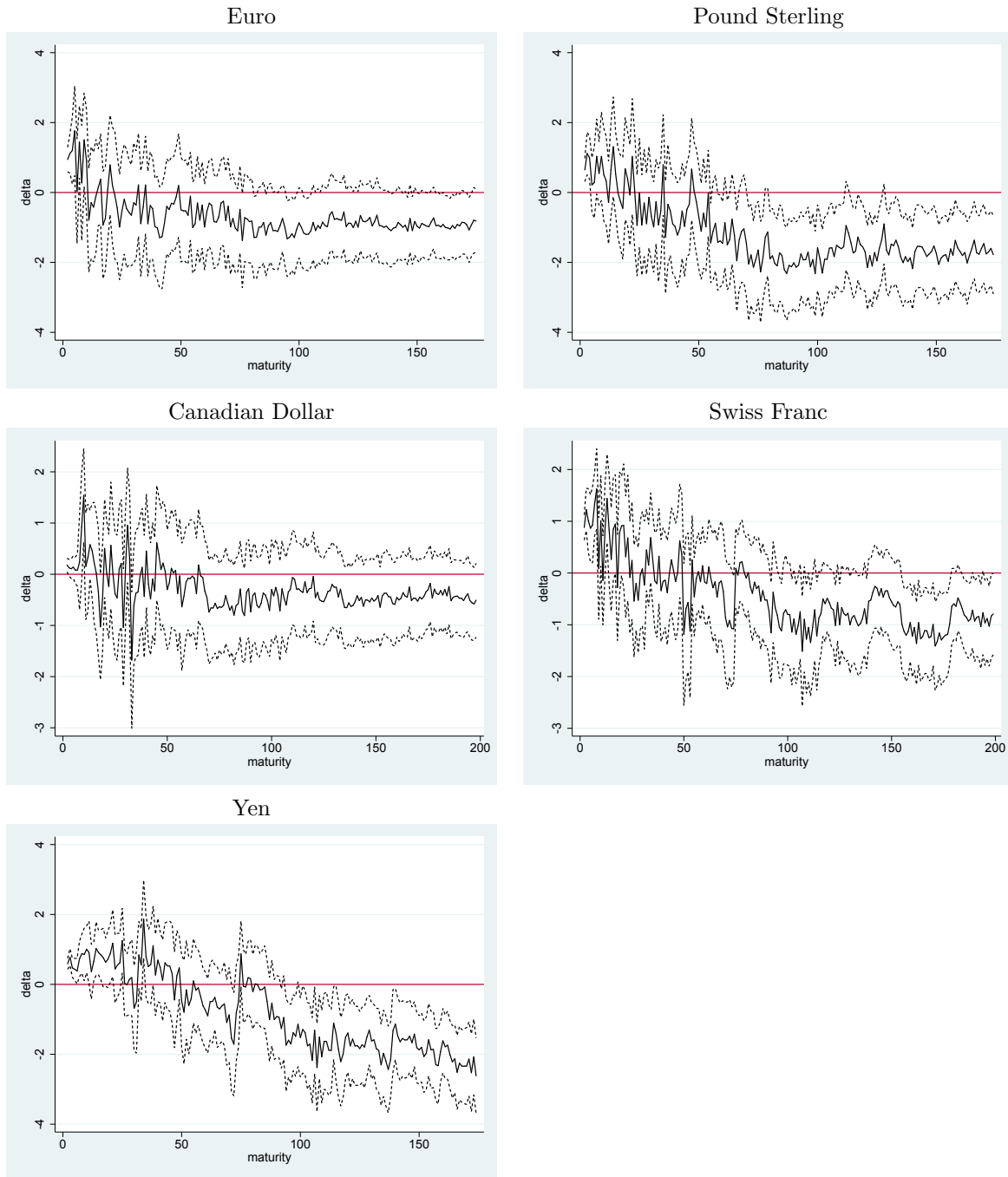
Notes: The upper and lower horizontal lines show the critical values for significance at the 95% and 90% level, respectively.

Figure 3: Structural Break Test for Selected Maturities (in months)



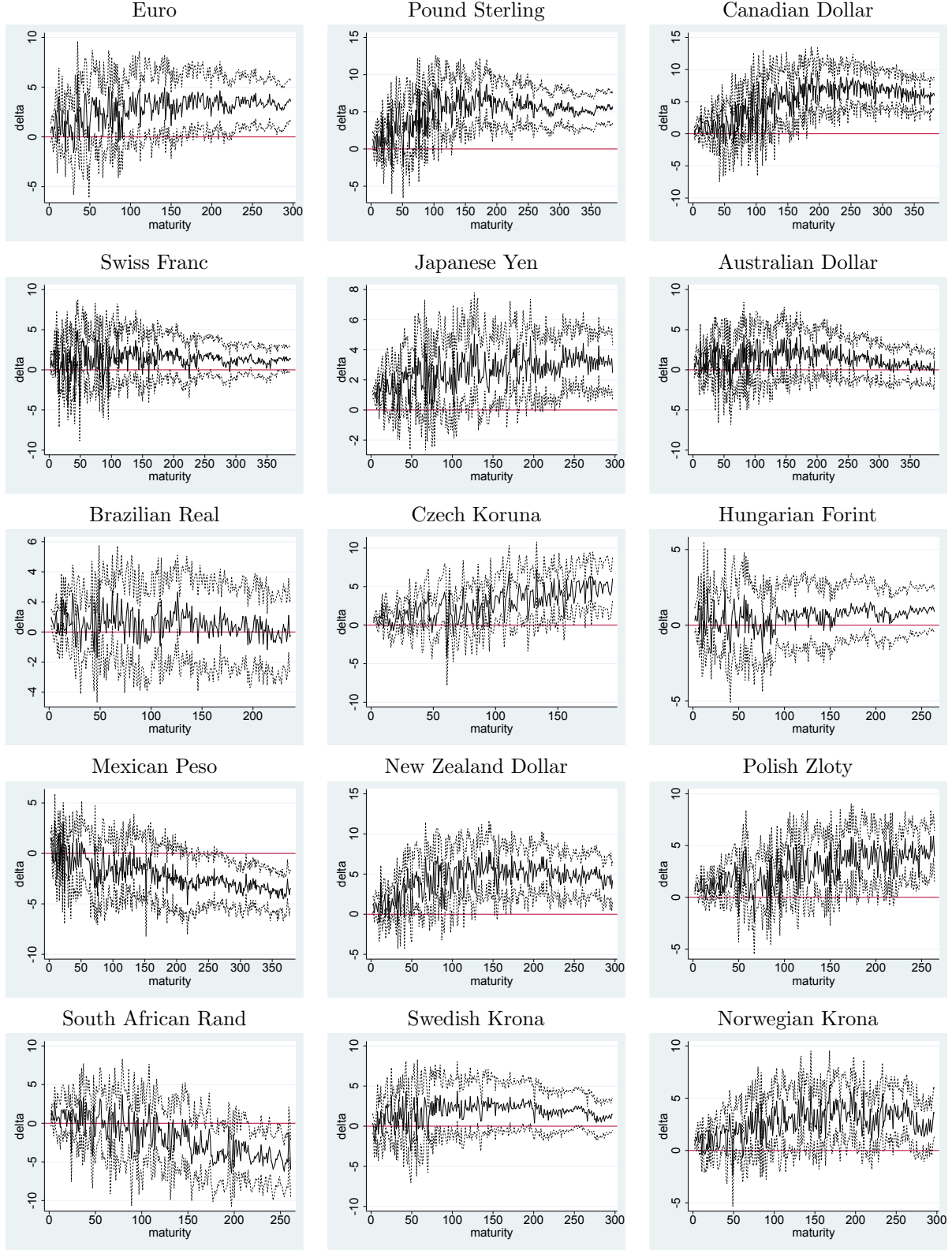
Notes: The upper and lower horizontal lines show the critical values for significance at the 95% and 90% level, respectively.

Figure 4: Structural Break Test for Selected Maturities (in months) (continued)



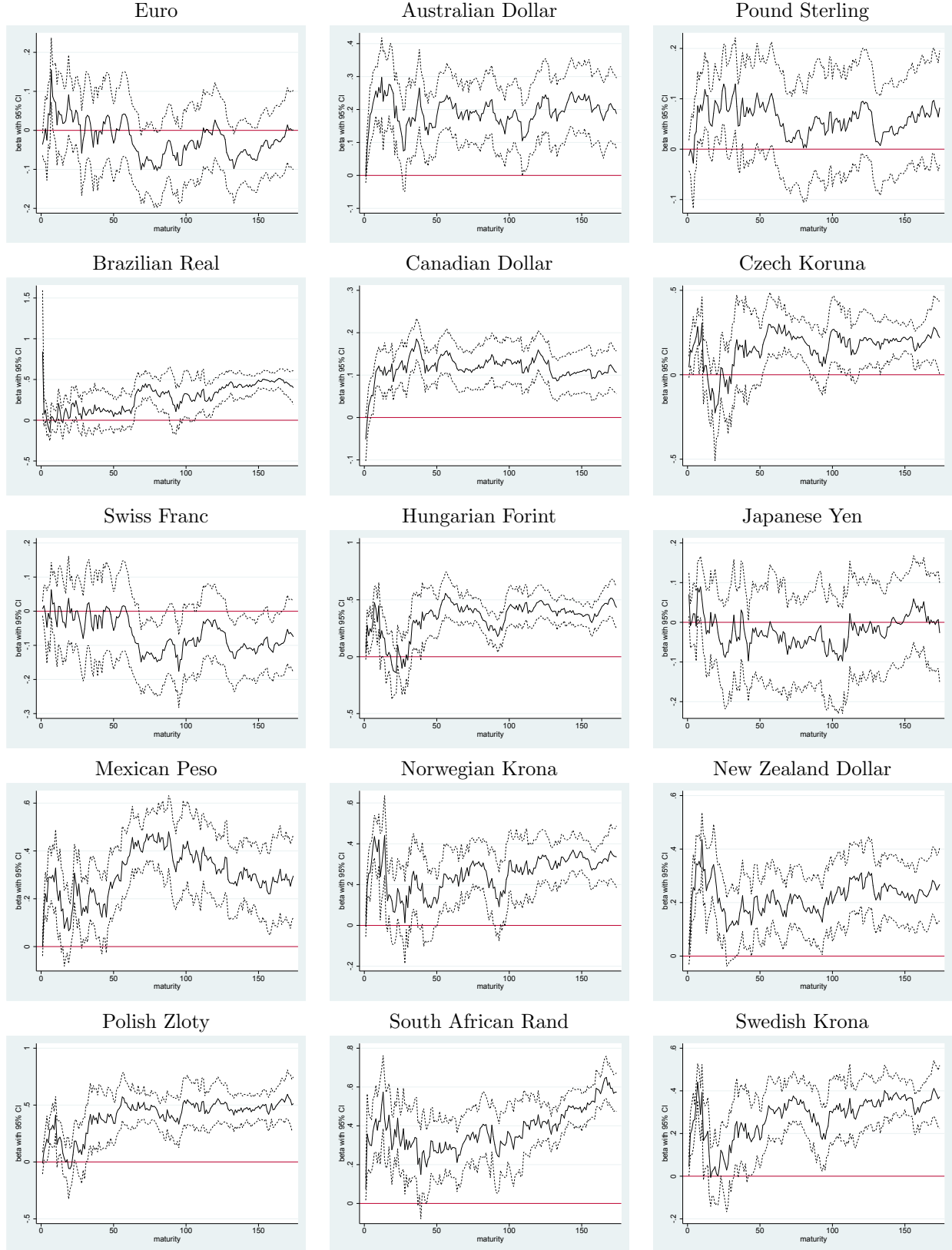
Notes: The upper and lower horizontal lines show the critical values for significance at the 95%, respectively.

Figure 5: Slope coefficients δ_m of the Fama regression: 1979 to 2007.



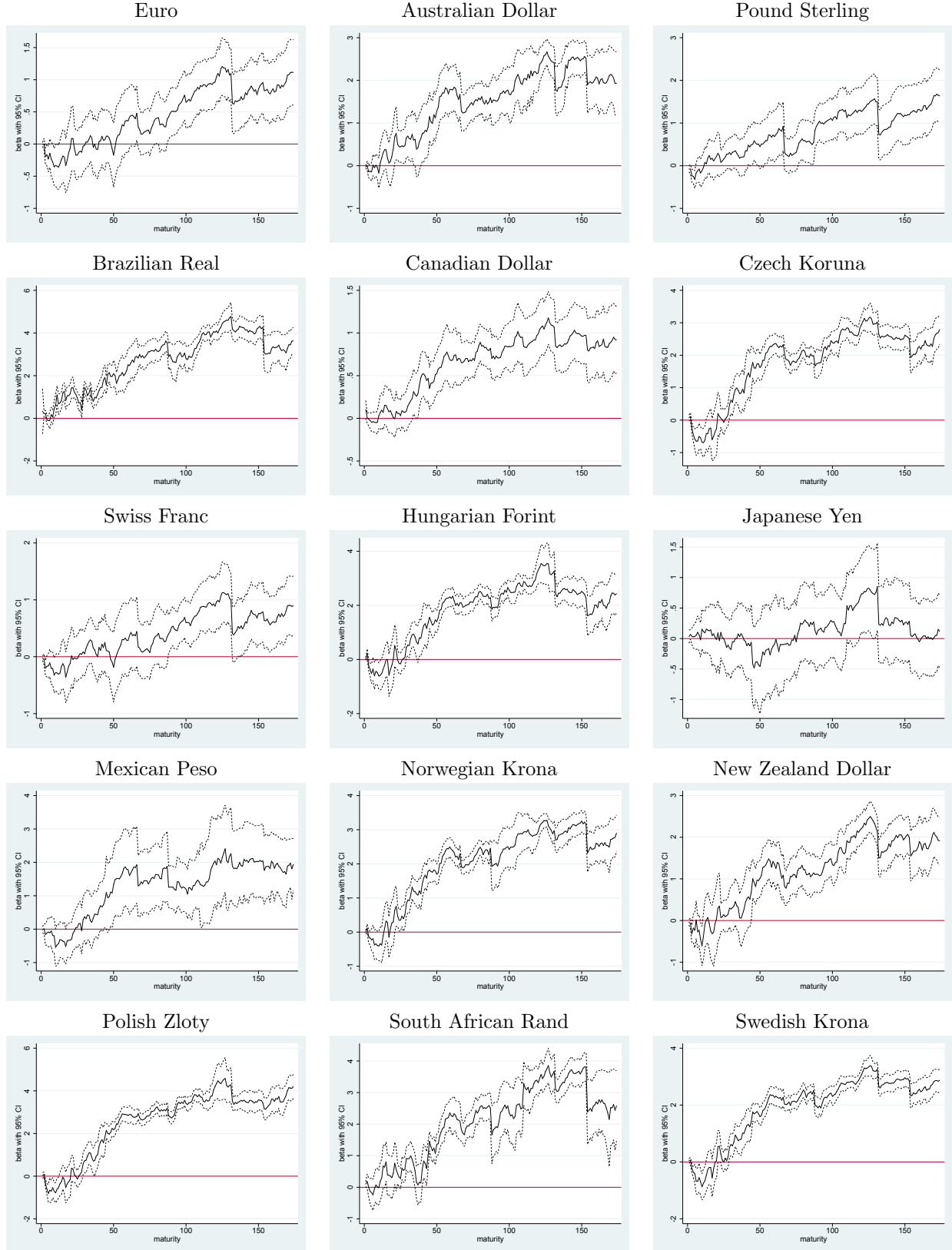
Notes: The upper and lower horizontal lines show the critical values for significance at the 95%, respectively.

Figure 6: Slope coefficients δ_m of the Fama regression: 2007 to 2018.



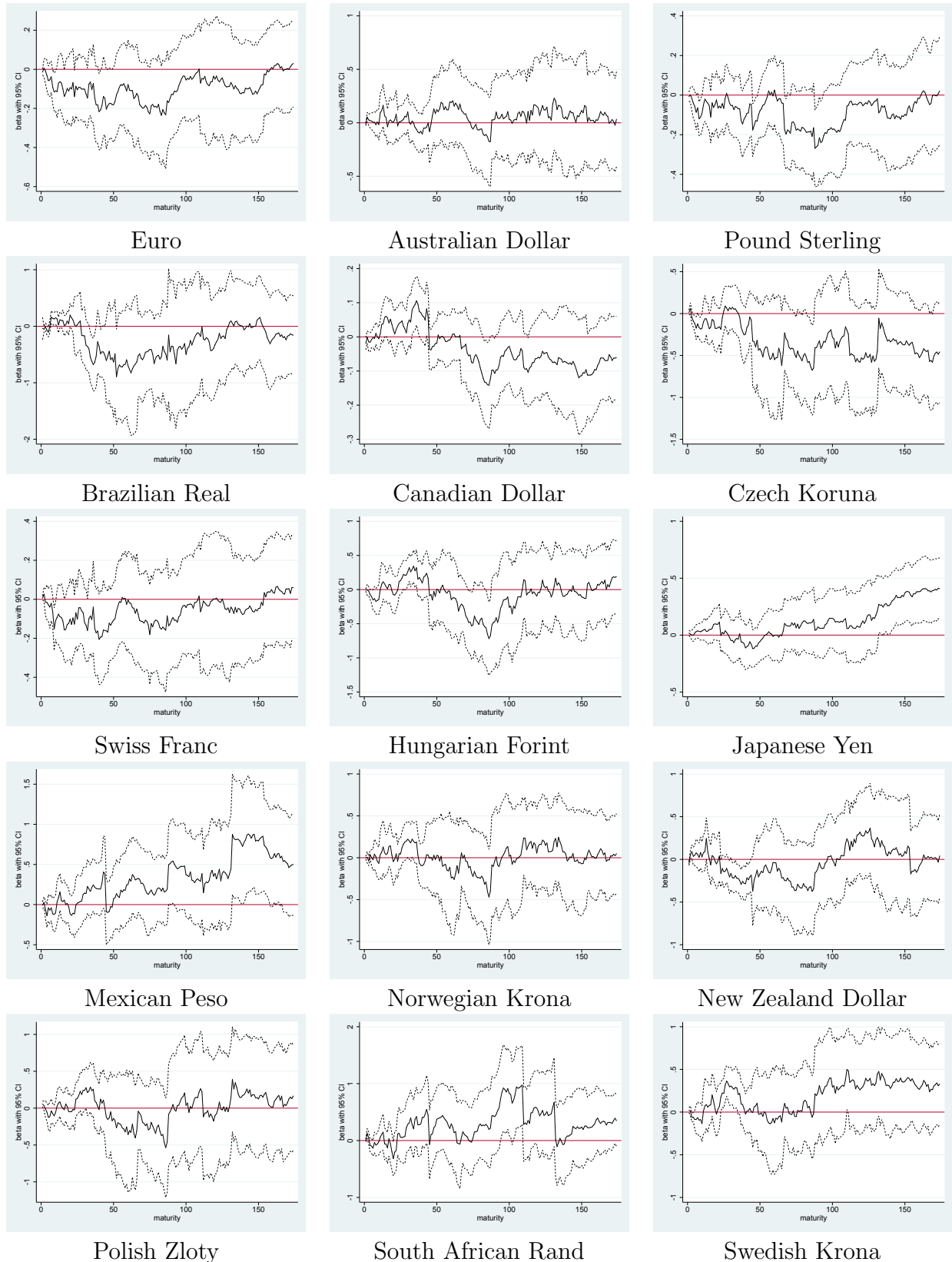
Notes: The upper and lower horizontal lines show the critical values for significance at the 95%, respectively.

Figure 7: Betas Market risk - 1979 - 2018



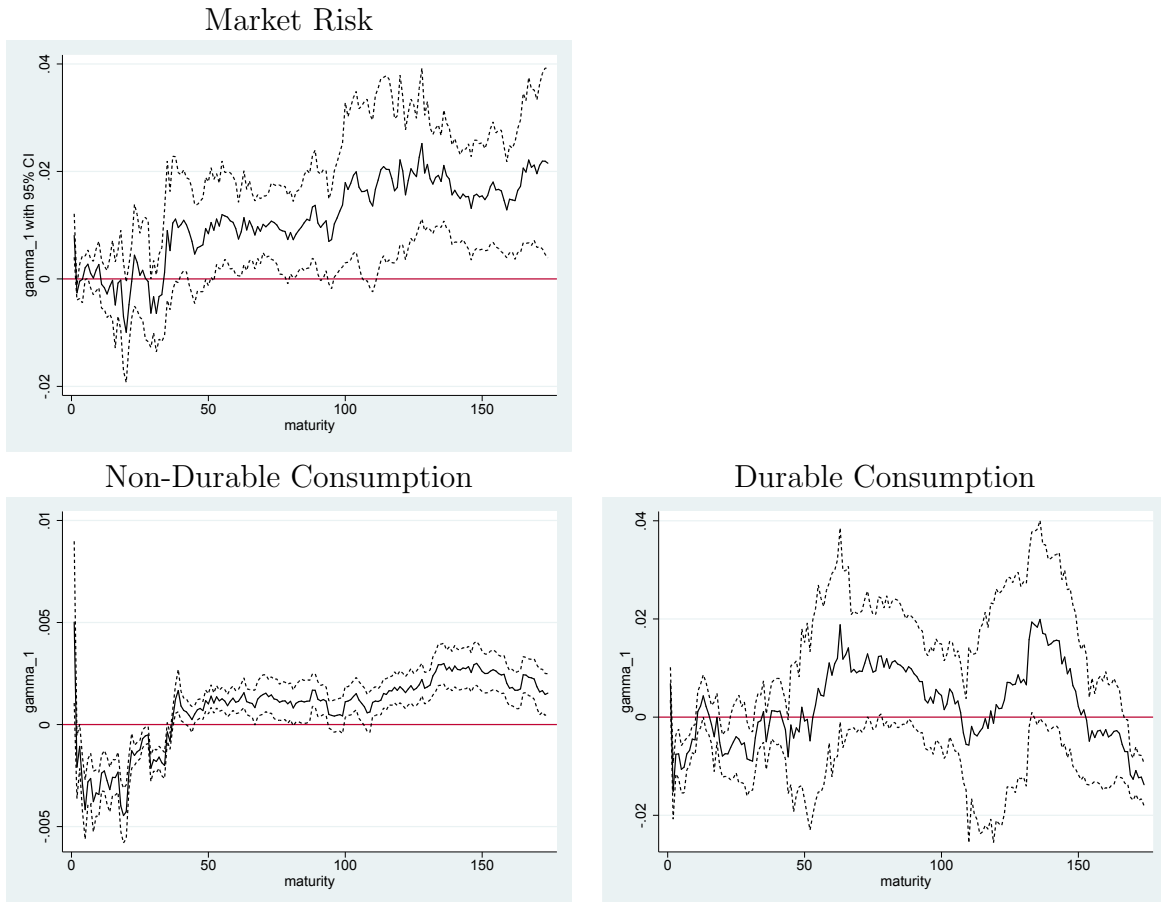
Notes: The upper and lower horizontal lines show the critical values for significance at the 95%, respectively.

Figure 8: Factor Betas - Non-Durable Consumption Growth Risk - 1979 - 2018



Notes: The upper and lower horizontal lines show the critical values for significance at the 95%, respectively.

Figure 9: Factor Betas - Durable Consumption Growth Risk - 1979 - 2018



Notes: The upper and lower horizontal lines show the critical values for significance at the 95%, respectively.

Figure 10: Risk Premium γ_1

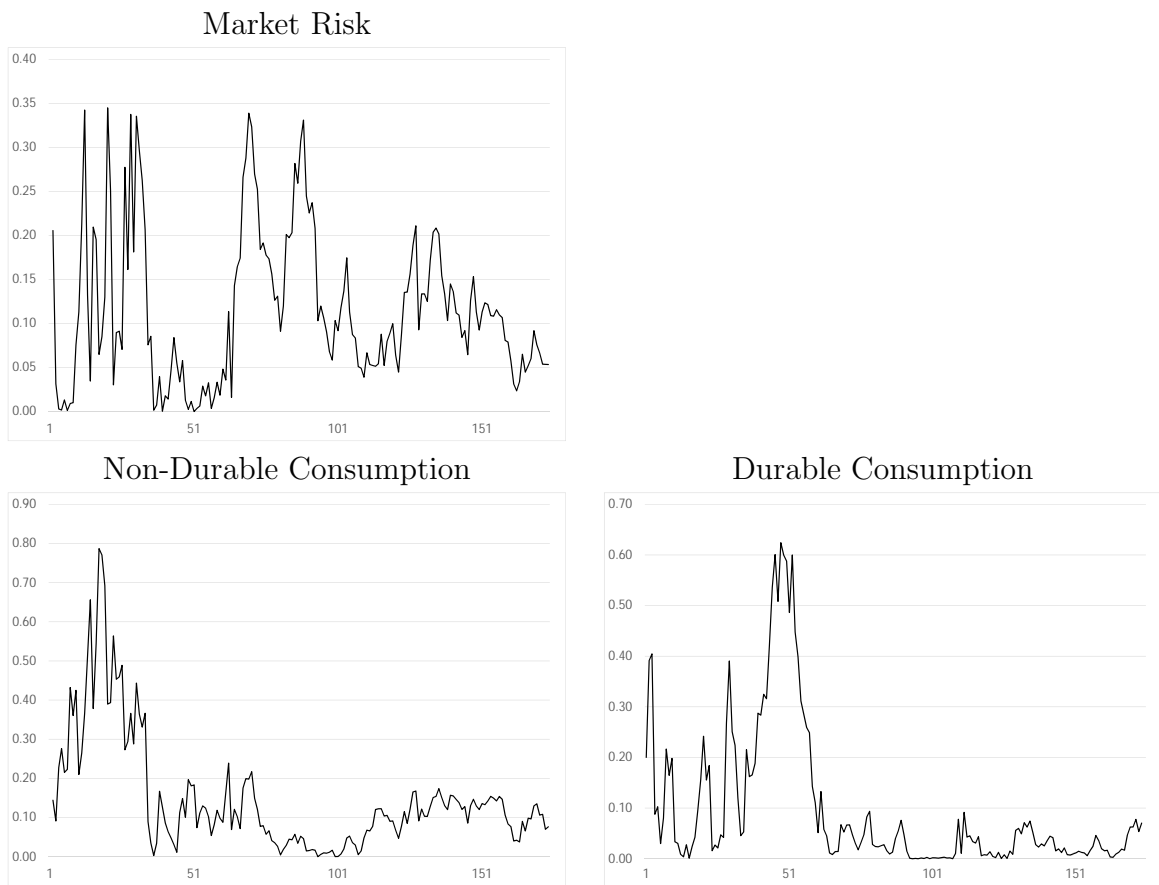
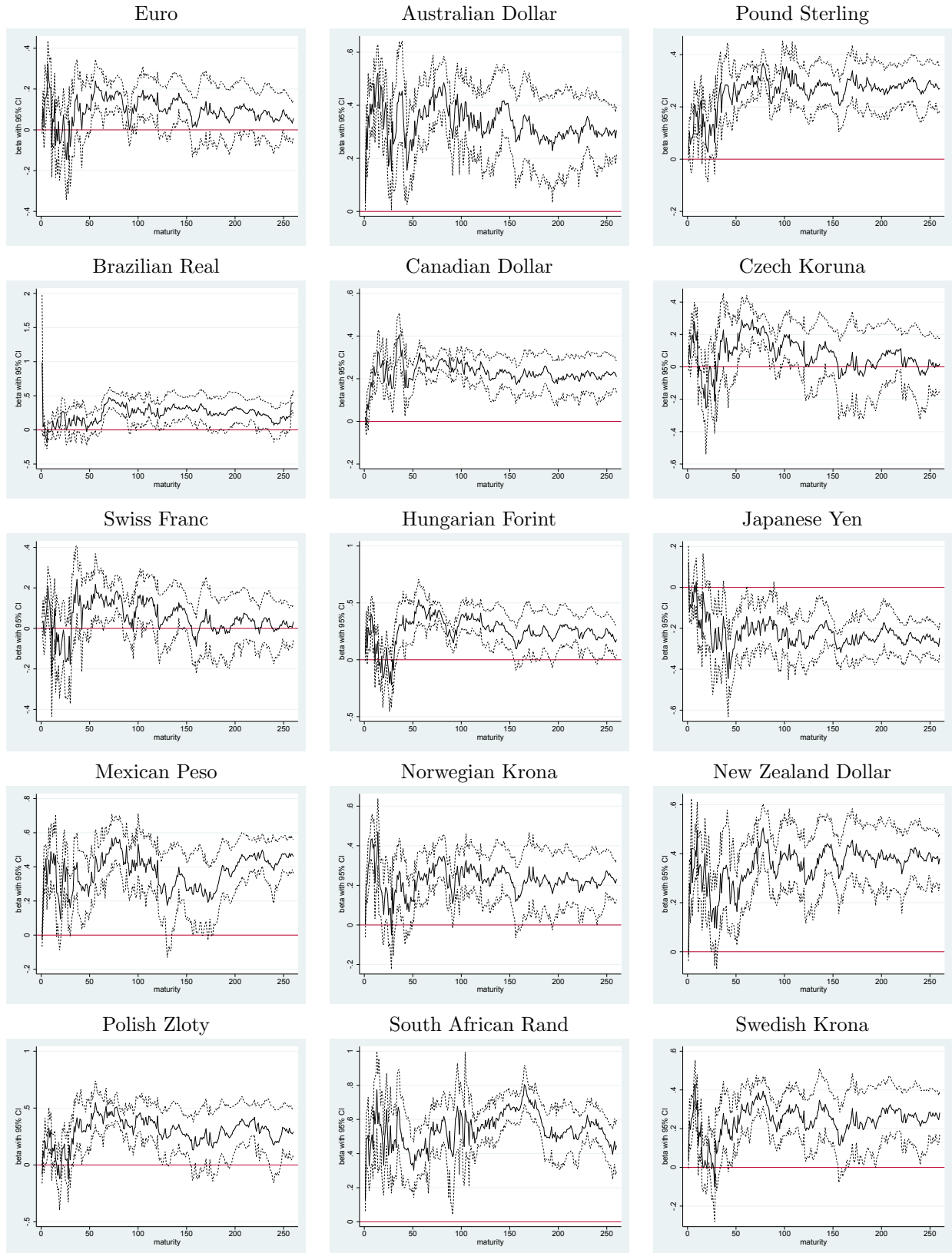
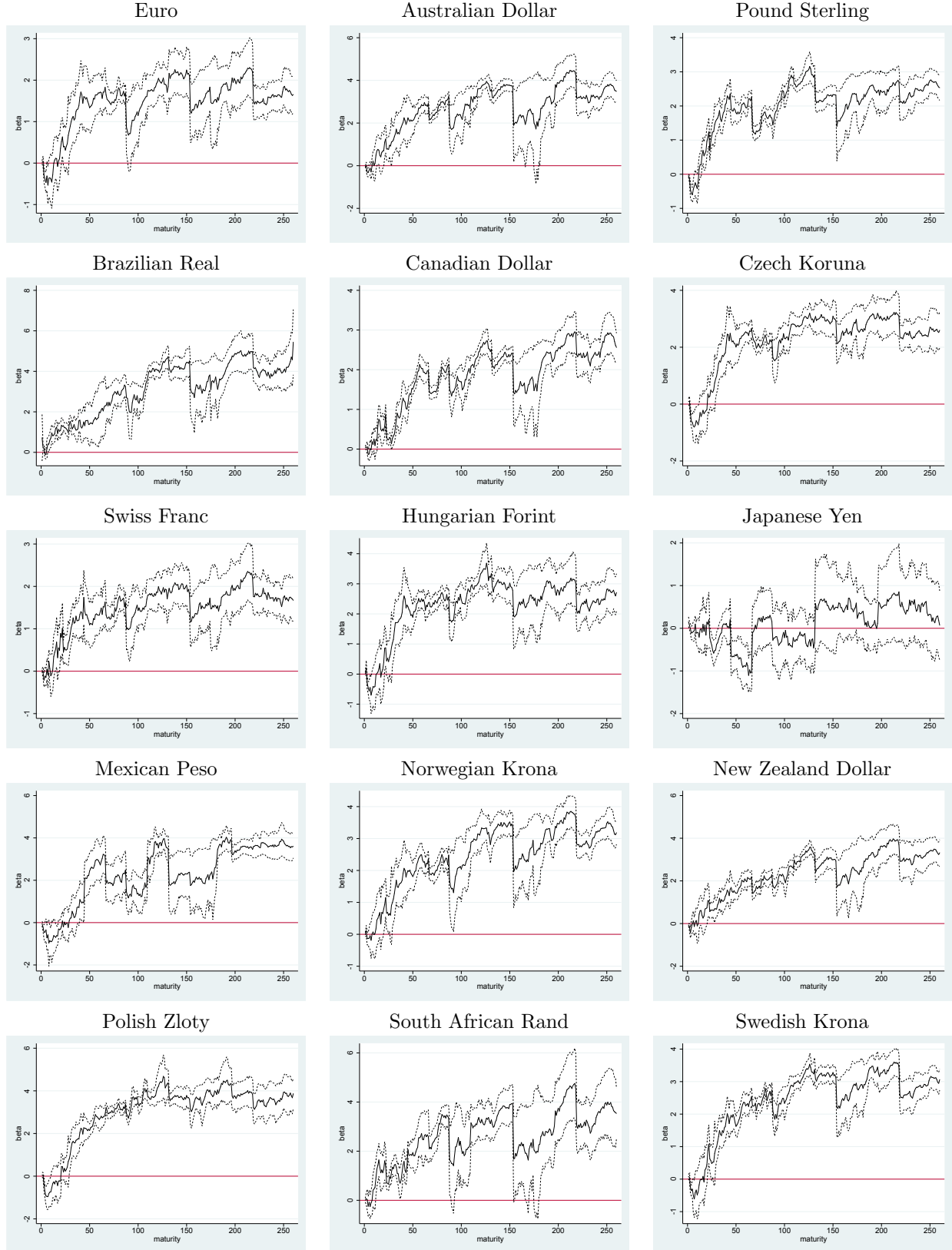


Figure 11: R^2 across the Maturity Spectrum - 1979 - 2018



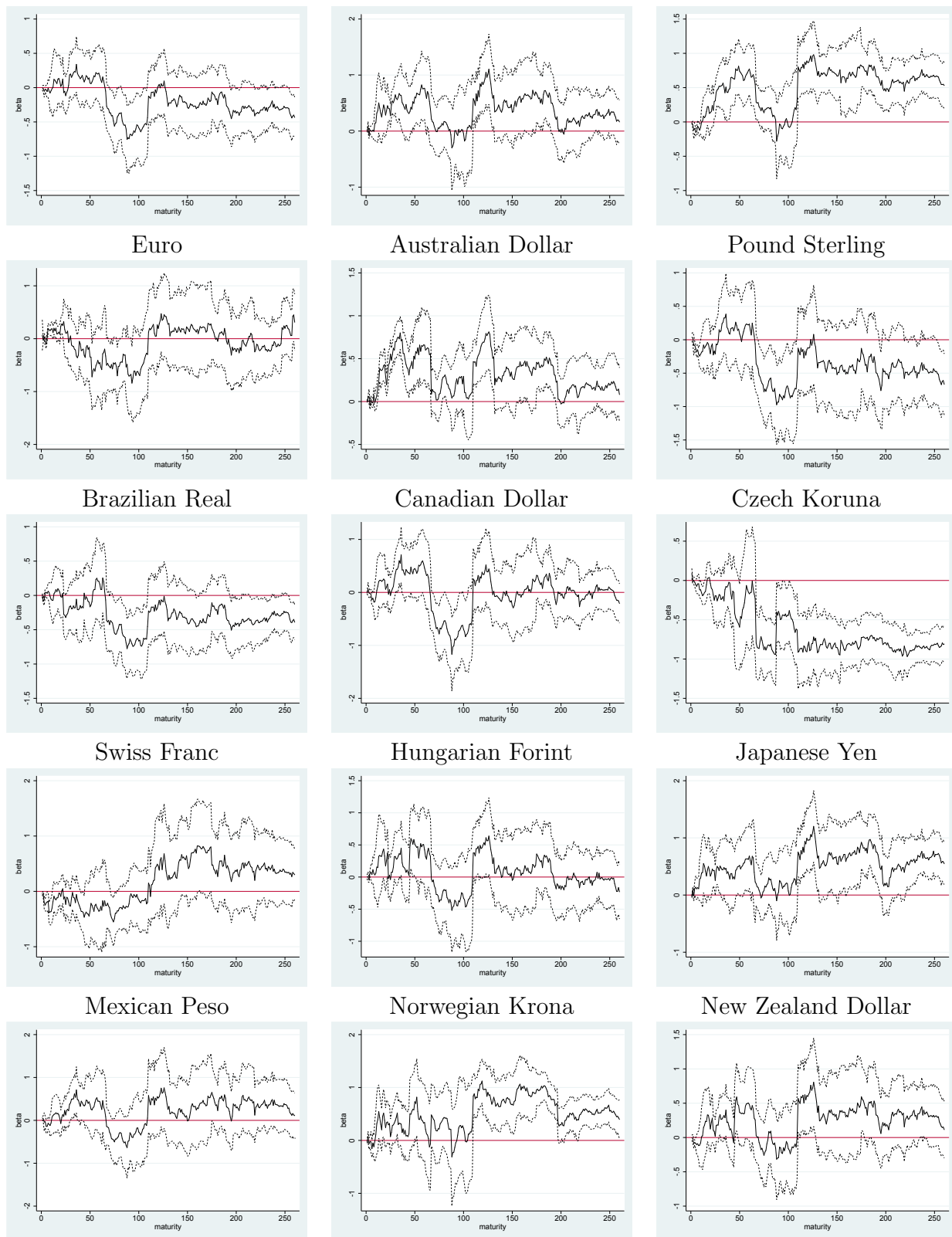
Notes: The upper and lower horizontal lines show the critical values for significance at the 95%, respectively.

Figure 12: Betas Market risk - 2007 - 2018



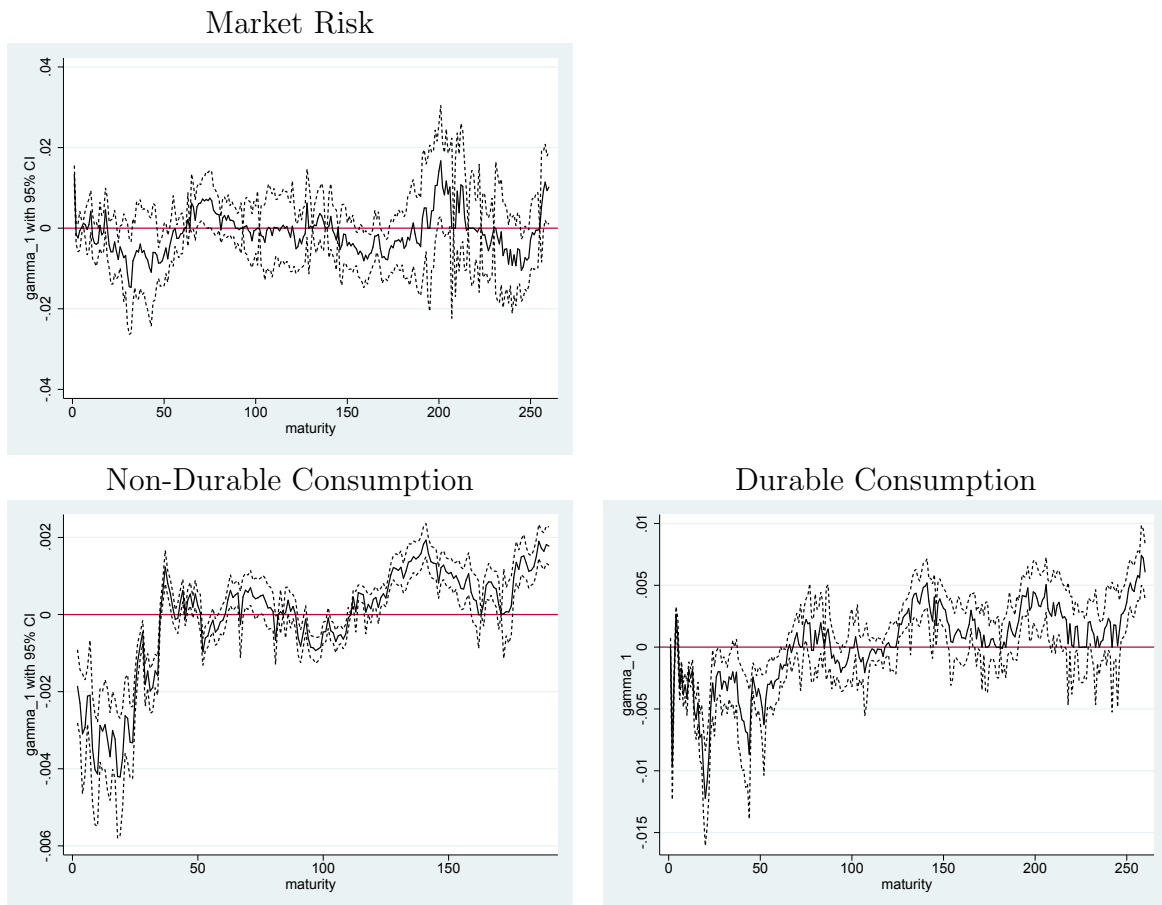
Notes: The upper and lower horizontal lines show the critical values for significance at the 95%, respectively.

Figure 13: Factor Betas - Non-Durable Consumption Growth Risk - 2007 - 2018



Notes: The upper and lower horizontal lines show the critical values for significance at the 95%, respectively.

Figure 14: Factor Betas - Durable Consumption Growth Risk - 2007 - 2018



Notes: The upper and lower horizontal lines show the critical values for significance at the 95%, respectively.

Figure 15: Risk Premium γ_1

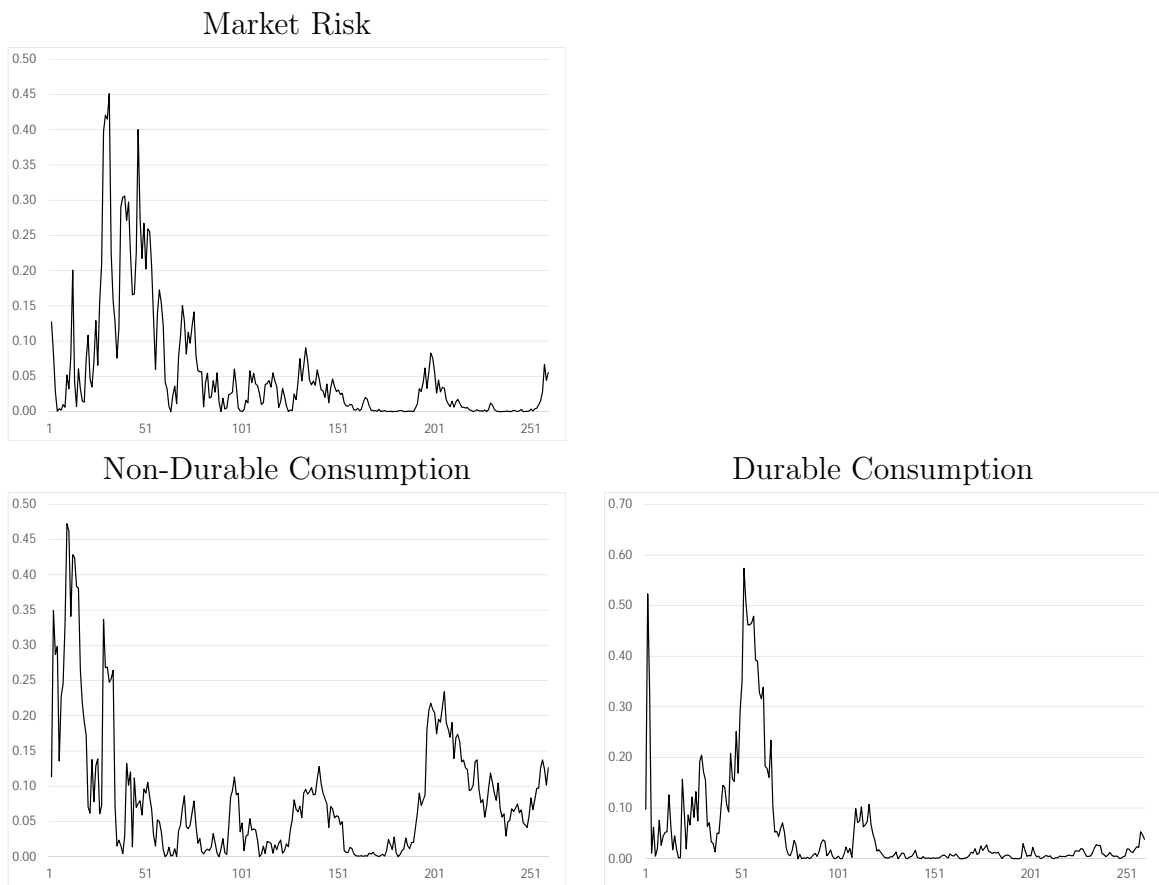


Figure 16: R^2 across the Maturity Spectrum - 2007 - 2018