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Economic and Financial Factors Affecting Currency Stability of Floating Exchange Rate Regimes: A Survival Analysis

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Approval of the Dissertation Committee

This dissertation has been duly read, reviewed, and critiqued by the Committee listed below, which hereby approves the manuscript of Istvan Zambori as fulfilling the scope and quality requirements for meriting the degree of Doctor of Philosophy in Economics.

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Abstract

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Currency crises can wreak havoc on countries economically, financially, and politically. This study has been conducted in the spirit of attempting to find a general notion of why such crises occur. The aim is to describe, based on empirical evidence, a general time dependent evolution of currency crisis probabilities. Furthermore, the goal is to uncover general and systemic variables driving currency crises.

The research utilizes survival analysis. Durations of tranquility are used to determine probabilities of crises. In turn, economic and financial variables are used to test possible linkages to these crises. In the study, durations of tranquil periods are defined by the absence of a downward pressure on the domestic currency. Pressure periods are defined by an 'Exchange Market Pressure' indicator. The end of a tranquil period is a crisis and probabilities of these are determined through the model.

The study revealed that the evolution of crisis probabilities over time are generally upward sloping. In the model these are shown by the hazard functions increasing. This implies that the more time a country in a tranquil period the higher the chances that it undergoes a crisis in its currency market. The conclusion holds for countries that survived to a particular time

thus, these probabilities are conditional. This suggests that time spent in a tranquil period does not lower the probability of having a currency crisis.

In the context of survival analysis explanatory variables are hypothesized to influence currency crises. Nine variables are included in the study: current account, direct investment, portfolio investment, IMF credit as percent of quota, real GDP growth, real effective exchange rate, unemployment, the LIBOR and the VIX. Of the variables included two have shown promise in robustly affecting currency crises probabilities. These were unemployment, and real GDP growth. Results suggest that a higher level of unemployment is expected to lower currency crises probabilities while increased real GDP is shown to increase them.

In the last section of the study country specific hazard graphs are drawn to compare the evolution of their respective crisis probabilities to the ‘average’ country. The comparison may aid investors in gauging the relative hazard of depreciation across countries and relative potential loss across currencies.

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I. Introduction

The collapse of a national currency can have far reaching consequences on a country's economic wellbeing. Having the right tools to detect a pending currency crisis can allow governments to adopt pre-emptive measures in advance and avoid a costly downturn. Although a precise forecasting construct of such crises had evaded researchers thus far, models based on probabilistic notions have made leeway in the discovery of certain factors causing calamities in a country's foreign exchange market.

Most previous studies that utilized a probabilistic approach to finding factors that influence currency crises have focused on binomial or multinomial discrete choice models. The shortcoming of such models is the assumption that shifts in currency regimes probabilities are the same for all future periods. Consequently, these studies have not considered the time-dependent nature of a country's currency regime. In this context, it is not realistic to assume that a country that had a currency regime in place for a longer time has the same probability of abandoning it compared to a country that had the same regime for only a year. Models of survival analysis takes this factor into account and test for duration dependence. The advantage of this approach is its implicit assumption that time dependence of a currency regime exists, and probabilities of abandonment or crises differ based on explanatory variables that change over time.

The survival model applied in this study focuses on probabilities of crises under flexible exchange rate regimes and on the determination of time duration before such crises occur. Additionally, the above probabilities are determined to be influenced by certain economic factors that yield significance in the crises of these regimes.

The dissertation first reviews the literature on currency crises in Chapter II. The review is focused on different statistical models and the variables that these studies found to be significant. This is the basis to derive testable hypotheses in this study. Chapter III details the econometric methodology used. Data sources and usage are summarized in Chapter IV. The mathematical definition of crisis specific to this model is described in Chapter V. To get the reader more familiar with the interpretation of the coefficient output in the tables an explanation is provided in Chapter VI. Chapter VII details the hypotheses, reasons of variable inclusion and the direction of causality on crises probabilities. Chapter VIII summarizes the results. At the end, a conclusion summarizes major findings and possible further research topics in this field.

II. Literature Review

Survival analysis has been used for data involving time to a certain event in the fields of biomedical research, criminology, sociology, marketing, and the health insurance industry. It has been known as ‘event history analysis’ in sociology, ‘failure-time models’ in engineering, hazard models in biostatistics and ‘duration models’ in political science and economics. The first life tables [used in the model] ever made for medical use was produced by John Graunt in 1662. In 1958 Kaplan and Meyer made seminal contributions by estimating survival probabilities and hazard rates. The proportional hazard model, also used in this study, was proposed by Cox in 1972. Survival analysis is a fairly new development in the field of mathematics and with the advent of computer science has just recently been utilized to tackle studies with large data sets. To cover relevant research publications a brief review of the literature is undertaken in the following section as it applies to the topic at hand, namely, currency crises. As the number of studies that combine duration analysis and currency crises are few the first section of the literature review covers the definition and identification of currency crises. The second section covers varying statistical methodologies used in the general currency literature in measuring a crisis for predictive and inferential purposes.

A. Empirical Identification of Currency Crises

The literature, in general, has utilized three somewhat similar methods to gauge pressure on the currency. The first group of papers focused exclusively on the exchange rate (J. A. Frankel & Rose, 1996; Osband & Van Rijckeghem, 2000) where only the rate and its moments are used to define a downward pressure on the currency. These moments are generally termed:

crashes. Typically, a threshold value of yearly or monthly percent depreciation is used along with a minimum increase (in depreciation) from the previous period. A second group of papers use a so called additive method to define crisis periods (Tudela, 2004; Zhang, 2001). First, exchange rates and their moments are utilized to gauge pressures relative to trends. A similar condition is applied to reserves. A crisis is defined when exchange rates and/or reserves additively signal a pressure on the currency. Lastly, the most prevalent technique is the use of a component pressure index. This exchange market pressure indicator [EMP], also used in this study, employs exchange rates, reserves and on occasion interest rates to define a currency crisis (Cardarelli et al., 2007; Eichengreen et al., 1996; Kaminsky et al., 1998; Sachs et al., 1996). Some studies only employed the exchange rate and reserves components in the EMP due to a lack of data availability (Kaminsky et al., 1998; Mulder & Bussière, 1999a). The EMP index measures the pressure on the exchange rate. Earlier studies measured EMP directly via monetary models whereas later papers identified pressures using indices that incorporate changes in reserves and exchange rates. Direct measures of EMP involve model dependency and focus on the extent of money market disequilibrium that needs to be balanced through reserves or exchange rate changes to reach a target rate. On the other hand, EMP indices are crafted to identify and/or forecast crises. Direct EMP measures lack comparable units, while the index approach has identifiable and consistent units making this method advantageous for time series or crisis duration studies.

The idea of an exchange pressure indicator was first put forward by Girton and Roper (Girton & Roper, 1977) using a monetary model. The EMP gauges the pressure on a currency. The index shows how the pressure evolves through changes in exchange rate fluctuations or via adjustments in reserves that is intended to counter exchange rate changes. One concern is that an exchange rate is a percent variation whereas a reserve intervention is a dollar measure. Girton and Roper assumed that the intervention through reserves is unsterilized. So, the intervention was equivalent to changes in the base money (m_0). Furthermore, using the purchasing power parity as an anchor they assumed that inflation in domestic prices is proportional to exchange rate changes. Thus, via transitivity, a one percent domestic base money intervention is equivalent to a one percent change in exchange rates. Consequently, when an intervention takes place, it has a potential to counter a pressure on the currency that is approximately equal in percentage terms. Given these assumptions, changes in exchange rates are added to changes in reserves, both in percentage terms, to form a currency pressure index. Their index is:

$$EMP_G = \%\Delta e_t - \%\Delta r_t$$

Eq. 1 Exchange Market Pressure Index

where e is the exchange rate (domestic over foreign currency) and r is reserves over money base. Equation 1 indicates that, for all time periods, an approximately one percent downward pressure on the currency can be countered by an equal one percent reserve sale in terms of the money base. Thus, to counter a one percent depreciation in domestic currency there would be a proportional sale in reserves [expressed in foreign currency] to prop up the lagging demand. Oftentimes, to offset this induced change in the money supply the Central Bank would conduct open market operations through the purchase of domestic currency denominated bonds to sterilize the intervention and restore the monetary base. This intervention in the bond market reduces or negates the effects of purchases of the money base ensuring to some extent independence of monetary policy. As open market operations result in changes in interest rates the EMP index frequently includes a third component, the interest rate, to gauge pressures on the currency.

B. Statistical Methodologies in Currency Crisis Literature

Currency crises and their causes have fueled a vast body of literature in empirical and theoretical studies. These studies have grown in scope and extent as varying explanations have been put forward to find roots of such crises. In the following section a brief survey of statistical methodologies is discussed and analyzed as they pertain to the current research. These approaches are leading indicator methods, Probit/Logit methods and survival analysis techniques. Each topic is discussed keeping in mind their relevance to this study.

Statistical techniques detailed below utilize the notion that a currency crisis either occurs or not based on some prerequisite. This gives rise to a dichotomous dependent variable. In literature, studies have also utilized continuous dependent variables representing the level of severity of a currency crisis. Such studies include Sachs et al. (1996), Bussiere and Mulder (Mulder & Bussière, 1999b) and Bodart (Bodart & Carpantier, 2020). In the summary below the articles all employed the notion of a binary dependent variable for a currency crisis. The focus on these works is explained by the fact that this study employs the same notion when determining a crisis.

B. 1. Signaling Approach

The signaling approach is used to catch signs of a pending crisis via early movements in economic and/or political variables. Survival analysis attempt to do the same except it uses the notion of probabilities. As the number of survival literature in the context of currency crises is scarce, the singling approach is utilized as a starting point to relate early movements of variables to currency crises. In what follows a general review of the most prominent studies are summarized and related to the current study.

Monitoring the evolution of certain economic variables is one method academia proposed to assess the chances of a sudden currency depreciation. This can enable market participants to undertake preemptive measures against risks a pending crisis can bring about. This so-called signaling approach is a non-parametric model. In its most typical application pertaining to currency crises a dummy variable is constructed from the general EMP index with a certain threshold limit, typically two or three standard deviations away from its mean. When this threshold is reached a crisis is registered. In turn, a variety of variables are monitored before a crisis occurs for possible signs of trouble in the Forex market. These so-called indicator factors are defined as variables that deviate from their normal levels above a given threshold value. Essentially, when this threshold value of any indicator is breached it is interpreted as a warning signal for a pending currency crisis within a given amount of time. In turn, variables that are found to signal a crisis can also be utilized in a survival setting to gauge possible relationships between the factors that cause a crisis and the probability of a crisis down the line.

The seminal paper by Kaminsky et al. (Kaminsky et al., 1998) conducted a study on 15 developing countries from 1970 to1995. The forecasting period is 24 months. They tested whether the variants signal a pending crisis in the 24 months prior to each crisis occurrence. The authors examined whether certain variables could signal a crisis defined by the EMP. The index threshold is set at three standard deviations above the mean, so passage of this value is defined as an episode of currency crisis. This is similar to how this survival study defines crises except for the standard deviation threshold magnitude. In Kaminsky's study signaling factors were chosen from pervious currency crisis literature that span multiple time periods and econometric methodologies culminating in a meta-analysis. The most promising indicators that showed the most potential in presaging a crisis were: low international reserves, high real exchange rate and credit growth, and elevated public sector credit and real effective exchange rates. However, excessive external debt and a current account deficit showed low proclivity to signal a currency crisis. The study also uncovered some interesting facts about how early the indicators can signal a crisis. According to the authors a banking crisis, high real exchange rates and high interest rates tend to signal a crisis almost a year and a half in advance and most factors they consider indicate a possible impending trouble at least a year prior a crisis.

Similar research to Kaminsky's was undertaken by Edison (Edison, 2003). The study focuses on 19 economic and financial variables. The data spans from 1975 to 1995. Like Kaminsky, the study uses the weighted EMP index but alters the crisis definition to 2.5 standard deviations above the mean of the index. Also, the period before the crisis is 24 months during which the variant can signal a good or false signal. The model output suggests that excessive movements in real exchange rates and low reserves along with equity market and output growth rates tend to signal a currency crisis. The study's main contribution however is the probabilistic forecasting technique wherein the chances of a crisis within the next x months are determined by the weighted signal indicator. This index is determined by the variants under study weighted by their respective signal-to-noise ratio. The composite indexes were elevated in most countries, especially in Asia before 1997 indicating a much higher probability of crisis compared to other years.

Adding to the literature in signaling Aziz et al. (Aziz et al., 2000) sought to isolate attributes of macroeconomic and financial variables in currency crises in emerging and industrial economies. They define the crisis by a sudden and large downward movement in the EMP. The model emphasizes graphical analysis. A time window is created around the crisis and movements in chosen variables are evaluated in this period. Comparisons are established so averages of the crisis years are compared to averages of the whole period. The authors conclude that prior to a crisis there is excessive inflation and current account balance problems along with undue growth in domestic credit. Additionally, increasing world interest rates and a declining term-of-trade intensifies the severity of the crisis.

Zhang (Zhang, 2001) highlights some advantages of the signaling approach. He points out that this model enables observers to quickly interpret the output by observing variables that move abnormally around their mean before a crisis. Moreover, looking at the number of variants that signal a crisis, a policymaker can get an idea of how imminent a potential crisis is. Opposing this is the notion of Abiad (Abiad, 2003) that highlights the shortcomings. He notes that the marginal contributions of the signaling factors cannot be extracted from this model. Likewise, as it is a non-parametric approach it is difficult to compare the outcome to other statistical approaches.

B. 2. Probit, Logit Approach

A statistical method that gained popularity in currency crisis literature is the Probit/Logit approach. This technique estimates a probabilistic relationship between the endogenous dependent variable and a vector of independent factors. The dummy binary dependent variable, with zero or one as inputs, enters the model and the probability of the output of unity is determined by the factor inputs. This probabilistic notion is commensurate to survival models that is used in this study. The Probit/Logit approach generates predictions accounting for possible correlations between the vector of covariates and enables calculations of significance for each input factor. The effects are typically reported as a one percentage unit change in the regressor on the probability of a crisis, evaluated at the mean of the data. Probit/Logit models enable us to gauge the effects of variables on currency crises. These variables can be lagged. Survival analysis, the model used in this study, also uses the notion that a crisis is caused by certain economic variables that are present before the crisis. The probabilistic notion and lagged variable causality make the Probit/Logit an excellent candidate for canvassing literature for potential variables inclusion in the study undertaken below. The following summary covers studies that were pivotal in launching the Probit/Logit method in the currency crisis literature.

One of the first articles taking advantage of the Probit model in a currency crisis setting was Currency Crashes in Emerging Markets by Frankel and Rose (J. A. Frankel & Rose, 1996). The authors attempt to characterize currency crises and their possible causes. Their dependent variable is a currency crash defined by a nominal depreciation of at least 25 percent and a 10 percent increase from the previous year. Once this threshold is reached the model registers the input as unity and records a crisis. The article entails numerous variants in the subcategories of macroeconomic, external, debt and foreign variables. The data includes two decades starting with 1970 and 105 countries. The approach excludes crashes that occur within three years to avoid counting the same crash twice. The results indicate that external effects have a strong influence on crisis occurrence. High debt, low reserves and overvalued real exchange rate all seem to increase crisis probabilities. Additional factors, such as: credit growth and increased northern interest rates also affect crises probabilities positively. It is essential to note that most variables found significant in this study overlaps with other significant factors in other currency crisis studies even though the statistical methods applied were different.

A seminal article by Eichengreen, et. al. (1996) conducted a Probit study on how a crisis in one country effect the probabilities of crises in other countries. Their focus is on the probability of a speculative attack initiated not by domestic or external misalignments but by the presence of a speculative attack elsewhere in the world. The spread of the effect of an attack on a foreign currency in this context is interpreted as contagion. The study defines the dependent variable as the Exchange Market Pressure index [EMP] that includes the sum of exchange rates, interest rate differentials with a reference country and differences in reserve growth relative to a base country. If the index surpasses 1.5 standard deviations of its historical mean it is considered a crisis. The EMP components are weighted by their volatility. In this context if crises occur in successive quarters is it considered the same crisis. Beyond the conventional macroeconomic regressors the study includes political variables. Moreover, covariates are included in contemporaneous and in lagged format. A major contribution is the inclusion of a contagion factor in the model. This is essentially a dummy input of one if a speculative attack occurred in any of the countries in the dataset. The results are somewhat divergent from other studies on currency crises. The authors conclude that high real effective exchange rate and unemployment tend to significantly increase the probability of a speculative attack along with crises anywhere else in the world. Altering the weighing scheme and changing the threshold standard deviation applied to the EMP did not alter the outcome much. In all robustness checks the contagion indicator was found significant, however most other hypothesized variables were proven to be trivial in the model.

Kumar (Kumar et al., 2003) use a simple logit model with lagged macroeconomic and financial data to assess if currency crises are predictable using these variables. 32 countries are pooled for the model. The crises are defined as five or ten percent changes in a composite index of exchange rate depreciation and reserve losses. The significant variables were real GDP, deviation from trend imports, portfolio investment, official debt and a contagion dummy. However, variables that are found to be important in other studies such as FDI and global liquidity were negligible in effect in this model.

One advantage of the Probit/Logit approach is that the effects of multiple factors can be summed up in one easily understandable number: the probability of a speculative attack occurring in the next x months/years. Furthermore, evaluation of marginal contributions to crisis probability for each covariate is possible. Despite the advantages there are a few drawbacks. First, it is problematic to assess what variables are out of line before a crisis and thus using these variables for early warning purposes is difficult. Second, these models can only evaluate the effect of a variable on a crisis given a particular period going forward. Namely, the model may evaluate the probability of a crisis in the next x quarters but does not look at probabilities in any given future quarter, per se. Consequently, the prediction holds for the average probability over the next x quarters rather than for specific quarters. Gauging how probabilities of the crisis change in a dynamic manner, rather than on average requires a different approach.

B. 3. Survival Analysis

Conventional statistical techniques measure cross-sectional or time series data to gauge the effects of variables on exchange rate movements. Only a few studies have addressed the persistent nature of such events. Survival Analysis [SA] is a group of statistical models that can be used to address the duration of time before a particular phenomenon occurs in the Forex market. The emphasis is: 'time before an event occurs' rather than an absolute date or a specific forecasting period. SA, like the Probit or Logit models, uses the notion of a dichotomous variable wherein the change in state, the event, is defined as a change in the variable from zero to one. In this setting, the model enables us to examine the effects of independent variables on the probabilities of a crisis in each period. In the process of modeling exchange rate movements SA allows the value of a variable to affect the probability of the event along a time path. Thus, this technique incorporates changes in covariates over time. Applications of survival analysis to exchange rate policy are far and few between. In the following sections articles pertaining to exchange rate policies and movements in Forex in the context of time duration analysis are reviewed. The main topics include exchange rate durations and speculative attacks on the currency.

In economic literature the predominant application of survival analysis in the context of exchange rates relate to pegged exchange rate duration. The general hypothesis is that time spent in a fixed exchange rate regime affects the probability of exiting from this arrangement. Walti (Walti, n.d.) used this notion to conduct a study on fixed exchange rates to assess whether time already spent in this regime along with other factors would affect the probability of it ending. Walti's study deals exclusively with fixed regimes rather than with exchange rate stability. As a result, he uses a 'de facto' classification of fixed regimes based on multiple statistics applied to movements of market determined nominal exchange rates. The indicator considers dual or multiple exchange rates as well as parallel markets, based on the actions of the Central Bank (Reinhart & Rogoff, 2004). As in all duration models a start and an end need to be specified for the event. The start here is the first month when the classification indicates a fixed rate arrangement. The exit occurs when the fixed rate is changed to another regime. Along with duration several variables are considered: inflation, growth, openness, real exchange rate, CB independence and quality of institutions just to mention a few. In the result inflation and CB independence are significant and positive implying that an increase in these factors will increase the probability of exiting from a fixed rate policy. Unemployment, current account and openness were also significant with negative signs suggesting that an increase in these will increase the chances of staying in the fixed rate arrangement. A vital conclusion of the model is the non-monotonic duration dependence. Essentially, this suggests that as time progresses while in a fixed rate program the probability of it ending changes in a non-linear fashion.

Examining fixed exchange rates in duration analysis opens opportunities to include multiple types of variables that can affect duration. Setzer (Setzer, 2004) studied fixed exchange rate duration in the context of survival analysis, however focused on political factors that can influence duration. Setzer, as Walti above, uses a de facto classification of exchange rates based on Levy (Levy-Yeyati & Sturzenegger, 2005) that classify regimes into fixed, intermediate, and floating. This is based on moments of nominal exchange rates and reserve volatilities. Duration of the fixed rate regime is determined by this classification. The study's main contribution is the inclusion of political factors that can affect duration. These are: partisan motives, election timing, veto players, degree of CB independence and type of political system (democracy vs. autocracy). The model also includes macroeconomic variables such as real effective exchange rate [REER], exports, and capital account. The included control variables such as REER and exports have shown significance in affecting currency crises. The main conclusion suggests that if the left is in power, if there are more veto players and when the central bank is more independent it is more likely that the fixed exchange rate regime will be abandoned sooner.

In the context of survival analysis Tudela (Tudela, 2004) had studied the length of time before speculative attacks are expected to occur on a currency. In her model, it is inherently assumed that exchange rate credibility is not only a function of reactions to speculative attacks but also a function of time already spent in tranquility (the absence of speculative attack). This time duration dependence can shed light on whether the likelihood of entering a speculative period is higher in the first months of the tranquil state compared to later months. Looking at the 1970-1997 period Tudela used a version of the exchange market pressure index to separate tranquil periods from times of speculative attacks. A period of tranquility is essentially the absence of speculative pressure. The assumption is that a speculative attack occurs when: a. exchange rate changes are greater than 1.5 standard deviation above the mean OR b. relative foreign reserves are below 1.5 standard deviations of the mean OR c. interest differential is above the 1.5 standard deviation mark. This is an additive method rather than an index method. Further speculative periods are added as additional requirements are met (thus the OR requirement). The model includes numerous variables among them domestic and external. Based on the model the main finding points out that export growth, openness, bank deposits and FDI positively affect the probability of staying in a tranquil period. However, an increase in imports and portfolio investments increases the probability of a speculative attack. It is important to point out that the additive method of diagnosing a speculative pressure may not be adequate in this case. If none of the three factors used to pinpoint a downward pressure on the currency move above (or below) their respective 1.5 standard deviation thresholds a crisis would not be defined in Tudela's model. However, a one standard deviation up move in the exchange rate and a simultaneous one standard deviation down move in the reserves cumulatively can show a crisis. This is because here a severe downward pressure in the currency is divided between the two factors under consideration. The countermeasures of the government to somewhat protect the currency is manifested in the running down of the reserves. Had this policy not been exercised the exchange rate would have depreciated below the 1.5 standard deviation threshold. In this scenario, both components in the EMP would contribute to the increase in the index which would signal a crisis in the domestic currency market. However, in this case the additive method would miss a crisis and thus would misidentify times of tranquility.

There are several advantages to survival analysis compared to other statistical techniques. When we introduce duration as an independent variable in the Logit model and examine the probability of exit from a state (fixed exchange rate, foreign exchange stability, tranquility) it either increases or decreases monotonically as time passes. However, this can be non-monotonic. Survival analysis does take that into account. Furthermore, incomplete observations, where fixed exchange rate regimes have not ended or speculative attacks have not occurred yet, are accounted for via duration in survival analysis. This so-called censoring does include information yet are mostly dropped from dataset in other models. Lastly, survival analysis enables us to extract multiple period interpolated probabilities for event occurrence rather than just for a specific period ahead.

III. Econometric Methodology

Many statistical models can be utilized to analyze panel time series data. However, only one takes advantage of the notion of duration. Survival analysis uses duration to determine time until an event occurs. This event is generally referred to as failure or exit from a spell. Typically, time duration analysis has been used in the medical fields and engineering. These models studied survival of patients with preexisting conditions or time to failure of manufactured products. In economics the notion of time duration models has mainly been applied in the field of labor economics. Some studies have looked at duration of employment (Aranki & Macchiarelli, 2013; Horowitz & Neumann, 1987) others used the model to examine spells of unemployment based on certain underlying factors (Uysal & Pohlmeier, 2011).

The goal of the following section is to briefly cover the method of survival analysis. This study focuses on exchange rate spells and speculative pressures on the currency so examples will be presented in this context. The exchange rate spell is represented by the duration of the exchange rate regime before a sudden depreciation pressure event occurs. To describe survival time, one can utilize four differing functions: the cumulative and density failure function, the survival function and the hazard function. The cumulative failure or lifetime distribution function can be expressed as:

$F(t) = P(t>T)$,where t is a duration up to t and T is a specific date/time

Eq. 2 Cumulative Failure Function

This represents the probability of failing or having the end of a spell occur at time T given the country survived up to time t. The first derivative of the cumulative failure function is the (event) density function (a P.D.F. density). This function, the f(t) thereafter, defines the probability of an event occurring on a specific date rather than up to it. The compliment of F(t) is the survival function that represents the chances of a random event/failure NOT occurring up to time t.

$$S(t) = 1-F(t) = p(T>t)$$, where t and T is as specified in Eq.(2)

Eq. 3 Cumulative Survival Function

The survival function is a decreasing function of time [or at least never an increasing function] with a value of unity at t=0 and zero as time extends into infinity [Also see Appendix: The Survival Function Definition]. The hazard function can be expressed as:

$$h(t) = \lim_{\Delta t \to 0} \frac{P(t \leq T < t + \Delta t | T \geq t)}{\Delta t}$$, t and T follow similar notions as in Eq.(2)

Eq. 4 The Hazard Function

This is a conditional probability. The hazard function shows the chances that a country will fail or have an event in the next instant given that is survived in a given spell up to time t. It can, for example, indicate the probability of the end of a tranquil period in exchange rate markets given that the 'normal' period lasted up to t. This 'hazard' can be influenced by country specific factors. As a result, a more common representation of the hazard function is:

$$h(t,x) = p(T=t \mid T>t) = f(x,\beta)$$, variables t and T are specified in Eq.(2)

Eq. 5 Hazard Function with Covariate Effects

This implies that the instantaneous probability of a country having an exchange rate event (a speculative attack or the end of a fixed rate regime) depends on the covariates of the country that are present today. Put differently, the variables affect the hazard of an exchange rate event occurring over time. It is of paramount importance to point out that this probability represents a conditional event, conditional on the country surviving to time t. Conversely, a probability distribution specifies unconditional probabilities wherein the notion of survival stipulates a probability of survival to exactly t years.

To further clarify the relationship of probability distributions and hazard functions we can express the hazard as a ratio.

$h(t) = \frac{f(t)}{S(t)}$, where f(t) and S(t) and the density and survival functions.

Eq. 6 The Hazard Ratio

The hazard can change depending on the interrelation between the f(t) and S(t) functions. It is evident that the ratio is time dependent and can be non-monotonic. As time progresses, the instantaneous failure can increase implying positive duration dependence, decrease suggesting a negative duration process, hold constant at a given level or as most often is the case, carve out a non-monotonic path. As both the density and survival functions range between zero and one the hazard rate can take on the value of zero proposing a zero risk of failure up to infinity claiming that failure is definite at that point in time.

There are different ways one can describe duration data and run inferential models. The most basic is the Kaplan-Meyer (Kaplan & Meier, 1958) [K-M] curve. This is a non-parametric model to describe the survival curve. This method uses the number of failed countries relative to countries still in the risk set at time t to graph a stepwise survival function. The K-M is composed of the product of conditional survival probabilities up to time t (Kalbfleisch & Prentice, 2011). Let t represent survival time, d_t be the number of countries who had an event at time t and r_t the risk set that signifies the number of economies that have not had a failure (a speculative attack) up to t. Then the survival can be described as:

$S(t) = \prod_{t=1}^{k}(1- \frac{dt}{rt})$, where d_t and r_t are as described above.

Eq. 7 Survival Time Function

This function describes the product of conditional failures. As time progresses the survival decreases by a factor $1 - \frac{dt}{rt}$ that represents the compliment of the failed countries as a proportion of those who are still at risk of failing (the risk set) [see Appendix: The Survival Function Definition].

Survival models can be parametric or semi-parametric in nature. A parametric model requires a specification of the hazard rate process beforehand. As hypothesizing a given hazard process is problematic given the lack of sound theory and given that a faulty description can result in large biases parametric models will not be considered in this study. Semi-parametric models do not make assumptions about hazard rates or the shape of the hazard function and thus are a better candidate for this study. The hazard is assumed to depend on a vector of explanatory variables x and is specified by:

$$h(t|x) = h_0(t) \exp(\beta_1 x_1 + \beta_2 x_2 + \ldots \beta_k x_k) = h_0(t)\gamma(x,\beta)$$

Eq. 8 Hazard Function with Explanatory Variables

This hazard describes how the risk of instantaneous failure evolves over time. In the above equation $h_0(t)$ represents the baseline hazard function that depends solely on time. This characterizes the probability of a country having an event (a speculative period on the currency) given that all covariates are zero. The benefit of this specification is that this γ function does not limit the β coefficients to certain values. γ needs to be positive as there is no negative risk of failure. Additionally, utilizing this hazard formulation is beneficial to the process of running the data as it uses the standard likelihood maximization procedure. [See Appendix: The Semi-Parametric COX Proportional Hazard Model].

The likelihood function is employed via the maximization procedure to find the beta coefficient components of the hazard function. Given the baseline hazard function drops out of the calculation the likelihood function using the hazard propose by COX is:

$$L[\beta] = \prod_{i:Ci=1} \frac{\exp(\beta' xi)}{\sum_{j:Tj \geq Ti} \exp(\beta' xi)}$$

Eq. 9 The Likelihood Function

In the above equation x_i is a vector of variables and T_i the observed time (failure or censoring event) and C_i be censoring. [$C_i = 1$: failure event, $C_i = 0$: censoring] at time i. This function indicates that only beta coefficients define this likelihood, consequently the function is independent of the hazard rate. The result is the absence of the baseline hazard function from the determination of the beta coefficients. Therefore, hypothesizing a hazard rate process is obsolete in this case. The log-likelihood is used to maximize the function and to find beta coefficients:

$$Ln(L[\beta]) = \sum_{i=Ci=1} \beta' x_i - \ln[\sum_{j:Tj \geq Ti} \exp(\beta' xj)$$

Eq. 10 The Log Likelihood Function

where C_i, T_i and x_i are as define in Eq.(9). [For further explanation see Appendix: The Partial Likelihood Function].

Applying the notion of survival analysis to exchange rate fluctuations this study investigates the occurrences of speculative attacks and/or pressures. In this context, duration represents the time when the exchange rate can be characterized by the absence of a speculative attack. The failure or event takes place when the country experiences a period of speculative pressure on the currency. Furthermore, the hazard function represents the instantaneous probability of a country having a speculative attack on its currency given the event have not occurred yet.

Assessing the probability of an occurrence in the future is not exclusive to survival analysis. Nevertheless, this method has certain advantages over other statistical techniques. In time duration data the same event may happen repeatedly. The nature of multiple events for the same observation is cumbersome to work with, however survival analysis is equipped with dealing with the notion of multiple occurrences of the same phenomena for any observations. Moreover, resolving the issue of incomplete information in the form of duration truncation, aptly named censoring, is a well-known characteristic of time duration models. One phenomenon of failure event studies is the plausibility of multiple occurrences for the same entity. A country may experience more than one speculative attack on the currency resulting in multiple durations of tranquil periods. If multiple events take place in the observation window the same country should not leave the risk set, but instead stay and contribute to the number of countries who are still under threat of a (or another) speculative attack. This is accounted for in the proposed model and included in the inferential regression.

A second advantage of the model is its ability to incorporate censoring into the data. Censoring originates from incomplete information about the spell or duration of the phenomena. In duration data distinct individuals/countries are followed through time beginning in the 'origin' state up to the point when the event/failure occurs. Censuring takes place when there is incomplete information about the time the object spends in the origin state and the precise time spent in this state is only known partially for a portion of the period. When the study begins a country may already be undergoing the 'spell' however the data only includes the origin when the period under consideration begins. This is called left censored data. Right censoring occurs when the spell had not ceased (the country had not had the event/failure) by the time the observation period ends. As data selection occurs mainly based on data availability or specified economic period such as pre- or post-recession periods the durations of exchange rate regimes are not fully recognized because the beginning or end may be outside the sample period. Un-censored data is just the complement of these wherein the failure occurs by the time the observation window closes, and duration of a spell is clearly defined. Survival analysis deals with these imperfections in information and incorporates both censored and un-censored observations into the model. In the study below the sample period is chosen considering data availability striking a balance between the number of attainable countries in the dataset and the length of time considered.

The survival model proposed by COX (Cox, 1972) assumes a proportional hazard. This entails that the ratio of hazards [risk of failing given it survived to time t: h(t)] is constant between two or more countries with different levels of covariates.

Let x_r and x_s be a vector of coefficients for country r and s. Then the hazard ratio is:

$$HR = \frac{h0(t)\exp\,(\beta\prime xr)}{h0(t)\exp\,(\beta\prime xs)} = \frac{\lim_{\Delta t\to 0}\frac{P(t\leq T\leq t+\Delta t\mid T\geq t,xr)}{\Delta t}}{\lim_{\Delta t\to 0}\frac{P(t\leq T\leq t+\Delta t\mid T\geq t,xs)}{\Delta t}} = \frac{h(t\mid xr)}{h(t\mid xs)} = \exp[\beta'(x_r - x_s)]$$

Eq. 11 The Hazard Ratio with Covariates

As equation 11 indicates the hazard ratio is not a function of time. This assumption suggests that a country with a one-unit higher covariate (GDP, reserves, etc…) has a higher **overall** rate of 'mortality' (instantaneous failure probability) This is different from saying that a one unit higher covariate changes the **pattern** in mortality **over time**. Further explanation can be found in Box-Steffensmeier, Event History Modeling: A Guide for Social Scientists (Box-Steffensmeier et al., 2004). Throughout the study the hazard ratios are reported as it is the baseline output for most statistical models. However, we can deduct the relationship between the beta and survival curve for any variable which gives a non-linear relationship [see Appendix: Interpretation of the Survival Output (Beta Coefficients)].

In survival models the conventional software output provides the Hazard Ratios (not the beta coefficients) for each covariate. Using equation 11 we can see that this indicates a ratio of instantaneous failure/event probabilities at time t given both the countries r and s survived to t. As a result, the output can be interpreted as a relative riskiness of country r failing at time t compared to country s given both countries survived to t. For the country with a one-unit higher covariate, the larger the hazard ratio the higher the risk of failing in the next instant, at time t, given they haven't failed up to that time. It is important to note that the ratio is composed of instantaneous probabilities. In the study this implies that the variable effects the probabilities in each quarter which themselves are different as time passes. Also, to interpret the HR, the condition is that both countries survive to time t.

When considering exchange rate spells and currency attacks varying groups of countries can be considered for the study. Emerging countries may have different survival probabilities in a tranquil period from developed countries. Time duration analysis techniques include hypothesis tests for differences in survival curves between two or more groups of countries. This so-called Lag-Rank [L-R] statistic tests the null hypothesis that there is no difference between survival curves of differing groups of countries. The test in essence compares the whole survival experience between two or more groups. In short, the L-R statistic looks at whether the survival curves overlap or not. Somewhat similarly the analysis examines whether the confidence bands of the survival functions intersect in a certain proportion. The test uses a chi-square distribution for hypothesis testing. The main conclusion of the L-R test is that on the 95 percent confidence one can reject the null that two or more of the survival curves are the same for differing groups of countries if the probability of the chi-square is less than 5 percent. It is necessary to emphasize that the K-M process tests the difference in survival curves between groups of countries not individual countries [for further explanation see Appendix: The Log-Rank Statistic].

IV. The Data

The sample period extends from 2000 January to 2020 July. The data is quarterly and includes 37 lower-middle and upper-middle income countries. The turn of the millennium was chosen as the starting date because variables are consistent and comparable across the sample of countries after this date. The dataset closely resembles emerging country categorizations. However, categorizing countries based on income rather that level of development gives a clear-cut definition on what is considered based on a single requirement rather than a group of characteristics that describes the definition of 'emerging'. Only floating exchange rate regimes are included in the study. These arrangements are chosen because, in general, they represent economies with more developed financial markets and more readily available datasets. Conditions in different exchange rate regimes may yield differing results in significance. In this research floating regimes are examined, and other regimes are left to other future studies.

The definitions of exchange rate regimes are based on the IMF's Annual Report of Exchange Arrangement and Exchange Restrictions. Variables were drawn from the IMF's IFS data base, the Federal Reserve Bank of St. Louis and Bloomberg finance. Countries that had adopted the Euro are excluded from the study. Only domestic non-Euro currency periods are registered for these countries. The data is quarterly, so all variables included are of the same frequency.

The variables included were selected based on the findings from previous crisis studies. These are: Current Account, IMF Credit as a percent of country quota, Direct Investment, Portfolio Investment, Real GDP Growth, Real Effective Exchange Rate, Unemployment, the 3-month LIBOR average and the 3-month VIX average. The Current Account, Direct Investment and Portfolio Investment are expressed as a percent of GDP to ensure consistency across countries and time.

Stock variables represent averages over the last 3 months unless otherwise noted. These variables are reserves, base money, domestic IMF credit, real effective exchange rate [REER], unemployment and the VIX. Flow variables are interest rate, GDP, current account, direct and portfolio investment, real GDP growth (growth in flow) and LIBOR.

Aside from flow and stock, variables can also be categorized into level and change classifications. Level signifies the actual numerical value of the variable. Change variables show the first derivative representation of the level formulation. Variables that are included as level in both the crisis indicator index or as regressors are: interest rate, REER, unemployment, LIBOR, and the VIX. Composite variables are also included as level variables. These are: current account, direct and portfolio investment. They are composite since they are represented as a percentage of GDP. Change variables are also included in both the crisis indicator index and as a regressor. Exchange rate and reserves are represented as percentage changes in the crisis index meanwhile real GDP growth represents a percentage point change year-over-year in the regression.

The EMP index components are measured on a quarterly basis to ensure the consistency between the dependent EMP index measure and independent variables. Measuring the EMP index in any other frequency [monthly, weekly] would not match the variable observations and would have to be smoothed to match the covariates.

V. Identifying Crises: Methodology

The notion of crises generally implies financial crises. Under this heading three general categories can be identified. These broad categories are banking crises, domestic and foreign debt crises, and currency crises. In this study only currency crises are examined.

A currency crisis occurs when a general perception exists among investors that a country will be unable to defend its currency in the event of an imminent sell-off. This typically occurs before a large build up in a country's liabilities when the ability of the government to honor its loans comes under scrutiny.

As pointed out, the focus of this research is on currency crises. However, it is important to keep in mind that banking, debt and/or currency crises can occur simultaneously. The 1992-93 Exchange Rate Mechanism [ERM] crisis was primarily a currency crisis, yet some Nordic countries experienced banking crises at about the same time. Indonesia's twin crisis at in the late 1990s exemplified that a sudden attack on the currency can elevate risk assessment that, if severe enough, can lead to further crises in the banking sector. However, the order of these crises does not imply causality. When a financial liberalization is coupled with poor supervision, weakness in the banking sector may only become apparent after a currency crisis. A speculative attack on the currency can destabilize confidence in the market that leads to banking and debt crises, yet these effects can be simultaneous rather that sequential. On occasion a crisis may not manifest in a sudden crash. If the buildup of the risk is gradual market perception slowly adjusts investment portfolios and capital can flow out of the country steadily rather than suddenly.

A. Measuring Currency Crises via a Downward Pressure in the Forex Market

In the following study periods of **downward** pressure on the currency are identified and dated using the notion of the Exchange Market Pressure index. The focus is on the depreciation of the currency. The EMP index can also be used to gauge an upward pressure on the currency. This would determine episodes that can culminate in appreciation. Countries frequently intervene when a currency appreciation occurs. This is often to avoid exports from becoming overly pricey in the market which would culminate in a reduction in GDP as demand for domestic goods would eventually wane. This current study solely focuses on periods of depreciation when the market sheds the domestic currency; due to either short lived investor sentiments or longer-term effects based on some fundamentals. Throughout this research sentiments are defined as “beliefs that are not justified by the facts in hand” (Baker & Wurgler, 2007, p. 129)

It is important to emphasize that a severe momentum to depreciate the currency is defined as a crisis in this context. A crisis can be triggered by short term speculative forces or investors looking for flaws in economic fundamentals. In the following section a summary is provided for the logic behind the two- and three-component EMP index.

An excessive pressure can include short term speculative attacks by investors [if longer than 1 quarter, as the study employs quarterly data]. In this context, the drive for short term gain by a larger enough pool of investors can put a downward pressure on a currency. This can be caused by perceived but unsubstantiated policy changes or altered risk assessments of a country. If such events occur, it can culminate in a correlated yet un-coordinated pressure on the currency. Fundamentals can also play a role in a downward pressure. This notion emphasizes longer-term misalignments of economic goals with actual policy actions. Excessive borrowing by the central government or consistently running balance of payments deficit can be a trigger to investors to cash out before policymakers are forced to realign goals and policies.

A crisis may ensue when there is a sudden stop in capital flowing into the country. This can severely disrupt output, private spending and credit to the private sector. If a large slowdown in capital inflows is persistent enough this can lead to changed investor perception and a selloff of domestic assets and a lowering of the exchange rate. On occasion the selloff of domestic assets can create a frenzy wherein the rate of the selloff is irrationally exaggerated. This can culminate in a destabilizing speculation.

A downward pressure on the exchange rate cannot be identified by solely observing the movements in exchange rates. When there are circumstances that may end in a depreciation the central authority may run down reserves or increase interest rates to avoid a drop in the value of its currency. Additionally, deliberate devaluations may be undertaken by the government to avoid a pending currency attack. Thus, actual devaluation, reserve adjustments and interest rate movements may all signal a downward pressure on a currency. In the best-case scenario, one could construct an index of pressure based on a structural model that could detect the excess demand [or lack of] for foreign exchange. Yet, a sound empirical model on the relationship between economic variables and exchange rates, applied to short and medium horizons, had eluded researchers thus far. Given this, a three component EMP index is constructed based on Girton (1977). In essence, the undesired excess supply for domestic exchange can be dealt with through three channels. First, the CB can allow the depreciation of the domestic currency. Second, the government can fill the gap in demand by selling and thus running down reserves to avoid depreciation, via an unsterilized intervention. Third, a deliberate increase, in domestic interest rates, through the purchase of sovereign bonds, can curb the excess supply of the domestic currency. Therefore, an index can be constructed to represent a speculative pressure on the currency: using Eichengreen (Eichengreen et al., 1996)

$$EMP_t = \alpha \frac{\Delta e_t}{e_t} - \beta \frac{\Delta r_t}{r_t} + \gamma \Delta i_t$$

Eq. 12 The EMP Index with Weights

where e_t is the domestic exchange rate (domestic/foreign), r_t is reserves divided by the base money and i_t is interest rate. The weights are defined as: $\alpha = \frac{1}{\sigma_e}$, $\beta = \frac{1}{\sigma_r}$ and $\gamma = \frac{1}{\sigma_i}$ that represent the inverse of the variance of each respective index component. In equation 12 both the exchange rate and reserves terms represent percent changes. To match the interest rate change is measured in basis points.

A crisis is defined as outlier values of the index:

$$Crisis_t = 1 \text{ if } EMP > X^*\sigma_{EMP} + u_{EMP}$$

$$= 0 \text{ otherwise}$$

Eq. 13 The Crisis Definition

where σ_{EMP} and u_{EMP} are the standard deviation and mean of the historical EMP of each country. In effect, the crisis is registered when the EMP is above its mean by X standard deviations. In literature, the threshold X ranges from 1.5 to 3 and is arbitrarily chooses by the authors (Sachs et al.; Kaminsky et al.; Zhang; Cardarelli et al.).

It is essential to point out that the EMP index may signal a crisis when the depreciation does not materialize yet there have been large movements in reserves and/or interest rates. This is the characteristic telltale sign of an unsuccessful speculative attack on the currency. This occurs a substantial portion of the time and needs to be accounted for as it represents a pressure on the domestic currency (Almahmood et al., 2020).

In equation 12 it is shown that the respective EMP components are weighted. As Eichengreen (Eichengreen et al., 1994) point out the weights should be deduced from an empirical model via the excess demand for foreign reserves. This would entail the cross-elasticity of exchange rates and reserves (as equation 12 include changes in percentages). This elasticity indicates the amount of reserves that would be needed to elicit a one percent change in the exchange rates. However, so far, academia has not succeeded in forging a theoretical model that could fit empirical observations well. As a result, this study will employ the weighing method proposed by Eichengreen (1996) called: precision weights. This is calculated by the inverse of the respective variables' variance in the index. This is represented by α, β and γ in equation 12. Weighing the components can have differing effects on identifying a speculative period. Giving too little weight to floating rates may understate an attack. Allocating to much weight to currency rates under a narrow band fixed rate regime can also understate a speculate pressure. With differing exchange rate arrangements, it is difficult to formulate an index with the right weighing factors that accounts for all contingencies under all exchange rate variants. However, as this study evaluates floating exchange rates exclusively the weighing method is consistent and thus comparable across countries. As Zhang (Zhang) showed, varying the weights had "little effect on the ordinal ranking of countries in terms of speculative severity". This notion suggests that severity of currency crises is relative to the severity of other crises and thus can only be ranked on an ordinal scale. Given this ordinal behavior, speculative pressures can be defined as outlier occurrences, as the order is constant and only the outlier requirement changes. This notion is summarized by equation 13 above with X representing varying outlier requirements in the form of standard deviation. Robustness checks can be applied based on the index by altering X to see if results are comparable. It is important to point out here that the EMP identifies the beginning of the crisis as a sudden change relative to trend. The start of the crisis typically occurs with a relatively fast momentum. Thus, deviations from trend show up clearly. However, finding the end of a crisis may not be so clear cut. The different components may never return to previous levels which, in turn, creates a new trend. As a result, finding the end of a crisis is more cumbersome. This is addressed below.

Before moving on to the definition of duration a point must be made. The EMP index utilizes the whole observation period to measure the mean and standard deviation of the EMP and gauges a crisis based on these moments when an outlier observation occurs. This method is used to uncover relationships between variables and currency crises. Yet, the above two moments of the EMP could be measured based on a rolling-window basis. This essentially would calculate the mean and standard deviation constructed from data samples that crawl through the whole observation period. This would be used more for a forecasting purpose. However, taking samples from the whole sample reduces the number of available observations in each 'window' which has the potential of losing important information that is present in the whole period. Thus, this study opted to use whole period moments to gauge currency crises.

B. Measuring Duration of Tranquility

Measuring time intervals of a phenomena require a continuous uninterrupted period of observation. As exchange rate regimes can be changed based on policy, duration of these regimes can end up stratified into multiple short lived time periods. This study only utilizes floating exchange rates to take advantage of longer and more available duration data for countries. The research employs the use of survival analysis to gauge the effects of various co-variants on the expected duration of tranquil exchange rate periods. The tranquil period is characterized by the absence of a currency crisis as defined by the EMP. Most works that utilized a currency crisis indicator defined periods of tranquility as the absence of a large magnitude downward pressure episode on the domestic money. Eichengreen (1996) utilized the EMP index to gauge when a crisis occurs and refers to a no-crisis observations as ‘tranquil periods’. This study adopts the same notion using the above EMP index (Eq. 12) as indicators of a currency crises and tranquility. In this study the tranquil period is defined as the length of time between the end of the last currency crisis and the beginning of the next one. The end of the crisis occurs when the EMP no longer satisfies the outlier requirement for a currency crisis as defined in equations 12 and 13. The start of a crisis occurs when this requirement is met for the first time.

C. The Exclusion Window

Most articles in academia use an exclusion window after the last identified crisis before a tranquil period is registered. If there is another crisis in that tolerance window it is considered the same crisis. Therefore, each speculative period ends Y quarters after the last crisis observation. If no crisis occurs in the pre-specified time exclusion window [Y] the tranquil period begins (Caramazza et al., 2000; Eichengreen et al., 1996; J. Frankel & Rose, 1996). Thus, the tranquil period begins Y quarters after the last crisis observation, defined by equation 13, and ends when the EMP signals a new outlier crisis episode (also presented by equation 13). This is identical to

Eichengreen's (Eichengreen et al., 1996) notion of tranquility. Typically, the length of this window ranges from 3 months [one quarter] to one year [four quarters]. In this study, these alternatives are utilized to conduct robustness tests where the exclusion windows range from one quarter to a year. It is of paramount importance to point out that in this set up when the exclusion window is set at Y quarters not only the two crisis episodes are coupled when the two crises are within this time period but also the end of the crisis episode is delayed by Y quarters even if there is no other crisis within this window. This is mainly to compensate for the difficulty to gauge the end of a currency crisis. As mentioned in the previous sections the end of a currency crisis does not occur with the same abruptness as the beginning of a crisis. When the crisis concludes the EMP components may settle at a new norm that alters the overall trend. This new norm takes a while to build into the trend. Consequently, the definition of the end of the crisis is allowed to change. Applying the same notion as above the definition of the end is altered between one and four quarters after the official conclusion of the crisis. This allows for the new trend to be registered and a new general definition of the outlier to be defined.

VI. Understanding the Model Output

A. Interpretation of the Hazard Function Applied to the Model

In the context of this study there are two basic ideas that the model uses. The first concept looks at how many cohorts [countries] will have a currency crisis **by** a certain quarter in the future out of the total at the beginning. This is essentially a cumulative notion of failure to a certain time going forward. The second notion establishes how many countries will fail in the next period [in our case quarter] out of those who have not failed yet **by** quarter one, two or t. This establishes the proportion of countries that fail in a specific quarter out of the number of countries that still haven't experienced a crisis. Stating simply, this gives the probability of a country experiencing a currency crisis in each quarter going forward. [For a more detailed explanation please see: C.8.2. Failure probability in a given quarter].

In this context, the study utilizes the second notion of failure called the Hazard Function to look at the probability of a currency crisis in a given quarter. Formally, the hazard function is defined as:

$$h(t) = \lim_{\Delta t \to 0} \frac{P(t \leq T < t + \Delta t | T \geq t)}{\Delta t}$$

Eq. 14 The Hazard Function Restated

This expression shows the probability of a failure at time T, in our case a downward pressure on the currency, occurring in the next quarter [Δt], given the country has not experienced any yet up to that point [T≥t]. The hazard function connects the observation points that yield a smooth continuous line [$\lim_{\Delta t \to 0}$].

To exemplify the hazard function, let's say the longest survival of any country in tranquility is 40 quarters and 100 countries survive in this state to at least one quarter. Also let's assume that in the first quarter 10 countries experience a crisis on their currency and after the second quarter this number increase to 18. By the third quarter 20 countries fail or have a currency crisis. This implies that in the first quarter 10 percent [10/100] failed who survived to quarter one, 20 percent [18/90] failed who survived to quarter two and 27.8 percent [20/72] failed that survived to quarter three. The proportion who failed is measured relative to those who survived to quarter one, two or three rather than relative to the total number at the beginning. In this example the Hazard Function would indicate a monotonically increasing function [10, 20 and 27.8] implying that more and more countries have a crisis event relative to those who survived **up to** the given quarter. In the framework of this study, the above example would imply that the more time passes, more and more of the remaining countries that have not had a currency crisis yet experienced one. This can suggest that if any country in the dataset was able to ward off a crisis on its currency for an extended amount of time it does not imply that in the future the chances will be lower that this crisis will occur. Simply put, in the above example, a long period of tranquility in a country's exchange market does not infer a safer currency implying that the length of time alone spent in a tranquil state does not reduce the risk of a pending crisis on the currency. This is the rationale in the above example. In this study a hypothesis is formed to test if there exists a time dependance of currency crises.

The hazard function looks at probabilities of failure in a particular quarter. However, the function looks at a range of countries and future time periods and applies the expected failure to this dataset. Some countries may adopt sound economic policies that may foster a quick resolution in a volatile foreign exchange market. Others may struggle with unstable political regimes that are prone to repeated crises. These differences are addressed in the next section where idiosyncratic country characteristics can affect the hazard function through hypothesized covariates.

B. Interpretation of the Hazard Ratio Coefficients in the Study

Survival analysis is a statistical process based on the probability of counties surviving the next period given they have not failed up to that quarter. The notion of failure is interpreted as the end of a particular spell, in our case the tranquil period in the domestic currency market. As described in the previous section the hazard function represents the conditional probability of failing in the next period given the country survived to that period. Put differently, the hazard function shows the probability of a currency crisis in a country in a particular quarter. The model coefficient output essentially shows the ratio of two instantaneous hazard probabilities as interpreted by equation 14 above. Thus, the hazard ratio [HR] coefficients represent the ratio of two conditional probabilities:

$$HR_{variable} = \frac{h(t,\beta_x,\beta_{y2} .. \beta_z)}{h(t,\beta_x,\beta_{y1} .. \beta_z)} = \frac{\text{h(t,one unit higher variable)}}{\text{h(t,reference level variable)}}$$

Eq. 15 Hazard Ratio with Variable Effects

Consider unemployment [u] as an example. If u increases by one percent (from 4 to 5 percent) then the probability of the currency undergoing a period of crisis changes according to the HR coefficient. If the HR output coefficient is 1.2 then a one percentage point higher unemployment today increases the probability of a crisis occurring in each period in the future by 20 percent [1.2 – 1]. Thus, if the probability of a crisis in a given quarter is 10 percent, we expect a 20 percent increase in this when unemployment goes up from 4 to 5 percent. This being the case, the new crisis probability goes from 10 to 12 percent. It is of vital importance to point out that the HR represents a percent increase [or decrease if it is less than one] in the probability of a crisis in a given quarter. This indicates that the HR shows a 20 percent [and not a percentage point] increase in the instantaneous probability of a crisis taking place in the country's currency market. If the HR is 0.9 than a one percentage point higher unemployment results in a 10 percent decrease in the conditional probability of the event occurring in any future quarters. Using the above example, when unemployment increases from 4 to 5 percent, in this case, the probability of the crisis goes from 10 to 9 percent. As the HR is a ratio of two probabilities its range spans the whole positive spectrum. An HR of unity implies that the coefficient has no effect on the probability of the event happening.

It is essential to mention here that the hazard ratio is assumed to affect the probability of a currency crisis in equal magnitude in each period in the future. This entails that when the HR is 1.2 an increase in the covariate raises the probability of a crisis by 20 percent in each quarter in the future. However, since the probabilities are not constant over time [see: Interpretation of the Hazard Function section above] the absolute effect of the covariate on any of these probabilities is different.

VII. The Shape of the Hazard Function and Hypotheses of Variables

This section is composed of **two parts**. The first half looks at the shape of the hazard function that signifies how the probability of a currency crisis evolves as we move forward. Using theories from economic literature a general shape is hypothesized for this curve. This is a non-parametric exercise looking solely at duration of tranquilities. The second half examines the variables that can affect the hazard function. In this section variables are hypothesized to shift the hazard function.

It is important to make a distinction between the two sections as they imply different conclusions about a currency crisis. The first part looks at how the probability of a currency crisis **evolves** as a country moves through time. The first section discusses this probability occurring going forward without **any** consideration given to variable effects. This non-parametric hazard curve simply indicates how many countries have a crisis by a certain quarter of those who still **haven't had** a crisis. The more a country spends in a tranquil state the chances of a crisis changes, and this traces out a curve which is called the hazard curve. The second section explores variable effects on the hazard curve. The variables in the model influence the hazard curve by shifting it up or down proportionally for every quarter. Thus, the curve, and every single crisis probability in each quarter shown by the curve, shift according to the directional effect of the variable found by the model output.

A. The Shape of the Hazard Function

The hazard function represents the evolution of the probability of a currency crisis going forward. Looking at the general shape of this curve can be informative. If the function increases monotonically, it represents increasing chances of a currency crisis as time goes on. This signals that **time spent in** a tranquil period increases the chances of a crisis in the future. One can argue that currencies are subject to international pressures that can turn against the currency. Lower interest rates in other countries may lead to depreciation pressures via the outflow of portfolio investments. Regional contagion effects can hinder investor sentiment about economic growth potentials culminating in a sell-off of the currency. These instances would lead to an ever-increasing probability of a currency crisis as time progresses if these factors are prevalent. Looking at the other end of the spectrum, when the hazard curve decreases continuously it signals an ever-decreasing probability of a crisis in the forex market. This shows that, proportionally speaking, less and less countries undergo a crisis the more time these states spend in a tranquil state. The implication can be that a country is building up confidence behind a currency as time goes on. This manifests in a lower probability of a crisis when the currency has weathered challenges without significant devaluation pressures. A government with a track record of low exchange rate volatility can be favored by investors. Through the capital account side of the balance of payments, a less risky currency can lead to longer maturity investments and/or less volatile returns. On the current account side, cross-border traders in goods and services are faced with less downside risks and uncertainties. This built up of trust can lead to less likely attacks on the currency the more time is spent in a low volatile state.

In theory, floating exchange rates should be more resilient to currency crises as one would expect a constant market adjustment to cap the buildup of pressures on overvaluation. This, in principle, reduces the probability of a currency crisis. However, countries with floating exchange rates have undergone crises in their forex market. The pegged and intermediate regimes, with a rather more ridged exchange rate, are associated with a greater susceptibility to currency crises, debt crises and sudden stops in capital flows (Glick & Hutchison, 2011). When "short time horizons discount the future cost of a currency crisis, the political incentives generated by pegged rates often fail to provide sufficient monetary and fiscal restraints to avoid such crises" (Willett, 2001). This is the case for emerging countries with open capital accounts (Ghosh et al., 2010). However, countries declaring a floating currency may be following a de facto pegged rate regime due to the so-called fear of floating phenomena (Calvo & Reinhart, 2002). This exposes the country to the risk of currency crises.

A floating exchange rate currency, by definition, adjusts to market forces and sentiments. However, this does not mean that countries with a declared floating regime will not try to intervene and manipulate the price of their currency. Reasons for this may be to keep the currency at a favorable price for trade or to avoid sharp depreciations in the future. This opens the door to instances of deliberately lowering the value of the currency as well to speculation. In this setting investors may see the forex as a rather unstable market. Overall, regardless of the regime any currency can be subject to speculation. If investors see the value of the money deviate from stated policy objectives or sustainable goals speculation may abound. This can be brough about by a myriad of factors.

One such factor can be the chronic undercapitalization of firms. When liabilities lead to high leverage coupled with low asset ownership of the firm an economic downturn can cause fire sales and in some instances credit rationing. At the extreme, this leads to a crisis. In instances, where companies foresee growth, adequate asset provision on balance sheets may be absent. This can arise when the economy has a period of long-lasting growth without any apparent sign of a slowdown. Companies expect to cover excessive liability positions with future cash flows that may never materialize. Given a large enough number of firms with inadequate asset base a small downturn can exacerbate the problem leading to bankruptcies and defaults. On a large enough scale this leads to foreign investors liquidating their positions, resulting in currency depreciation. As the business cycle dictates that an eventual economic slowdown will occur, firms with low levels of assets can cause an eventual exodus of foreign investors from the market. In a sense overconfidence in future economic growth eventually leads to the shallowing out of sufficient cash flows relative to liabilities. Therefore, we can expect that these firms will contribute somewhat to an eventual currency depreciation. Eventual, in a survival sense, implies that as time goes on, with firms continuing to have a shallow asset base, the contribution to the probability of a devaluation increases. This suggests an ever-increasing probability of a currency crisis partially due to firms having low asset ratios.

One reason for speculation is the ability to take on large liabilities in the form of lax lending practices. Firms increase leverage in the hopes of generating higher returns. However, if growth perspectives do not materialize firms' ability to repay debts vanishes and a market collapse occurs. This can take place on a global scale or on a country specific level. If asset prices start deflating and firms are not able to honor liabilities, investors cash out and a sudden depreciation may occur. The longer easy money provisions continue the larger risks these firms will take on in the form of leverage. Unsound lending practices eventually leads to default, en masse, and a market slowdown. As in the above case, 'eventual' here implies that the probability of a devaluation increases, which suggests an ever-increasing probability of a currency crisis as time goes on.

Another reason why the currency may undergo a period of downward pressure is due to liabilities being denominated in foreign currencies while assets are in a local currency. Banks that "enjoy government guarantees have an incentive to increase their foreign currency denominated liabilities and incur foreign exchange risk that are underwritten by the deposit insurance system" (McKinnon, 1999). In fact, governments can also take advantage of guarantees, if in an economic union, to finance deficits by taking on more debt. This happened in the Greece euro crisis when the country overborrowed culminating in a credit crisis by 2009. As a result of explicit guarantees firms can rely on lower risk perceptions of the domestic financial system to overborrow from foreign investors. Under such pretenses unexpected depreciations will deteriorate bank, government and corporate 'balance sheets'. Foreign currency denominated liabilities will exacerbate loan repayment issues that can culminate in loss of confidence. As debt becomes increasingly unmanageable, this leads to higher probabilities of outlier depreciations because the number of insolvencies rise. From a portfolio perspective, the downside risk of holding a currency is exacerbated leading to higher risk perceptions. Thus, the longer a bullish period lasts, characterized by a buildup of excessive foreign credit, the more likely the crisis will occur. Putting this into a survival context, the longer a tranquil [expansionary credit] period prevails the more likely a currency crisis takes place.

Looking at a sudden depreciation of a currency can be a sign that a bubble bust in the market. When a bubble starts increases in prices are justified by innovations and policies. This can manifest in increased foreign investments and capital inflows. "The success of capital inflows generates encouragement for further inflows which push adjustments well beyond what is warranted by fundamentals (Willett, Chiu, and Walter 2014, 18). When the price increase continues without justified fundamental factors a self-generating bubble can culminate in an investment boom. It has been suggested that "booms become bubbles when momentum takes over and speculators invest only because price has arisen" (Rapp, 2009, p. 7). The psychology of the crowd takes over and a herding behavior pushes the market ever higher. This can turn into euphoria. Under these circumstances the reason why "asset managers do not bet against the market is because while the market continues to rally their profits will be below their competitors and investors with short time horizons may take their money elsewhere (Jones, 2015; Willett, 2021). Additionally, Kindleberg, et al. assume that investors have "selective memory" and such behavior leads to them "paying too little attention to news that conflicts with their optimistic narrative" (Aliber and Kindleberger 2015). Schiller suggests that "feedback loop dynamics can generate complex random behavior" (Shiller 2015, 87). This complex random behavior can, given the right circumstances, result in a crisis. Furthermore, agents often fail to differentiate between stability and sustainability. This culminates in excessive risk taking and credit booms that carries an ever-increasing likelihood of a crisis (King 2016). Put into practice, when crises are tallied and summed up in a survival setting this gives a probabilistic description of the event. This can identify the likelihood of a crisis and let investors discover inter-temporal market perceptions. In terms of a currency crisis, the increasing risk taking, and the short time horizon of investors coupled with over-optimism leads to a feedback phenomenon that results in ever-increasing chances of a crisis and a cash out from the market. So, a longer period of calm justifies more risky behavior escalating the probability of a currency crisis ever more.

Hyman Minsky argued that an economic cycle is driven by excessive speculative activity that is defined by a bullish period followed by a market collapse. Excessively bullish periods may begin because over time agents tend to forget the effects of previous crises. Minsky postulated that abnormally long bullish periods will cause market speculation that eventually lead to market instability and collapse. This buildup to the crisis is characterized by market speculation. The speculation is driven by borrowed funds. Once a prolonged decline in asset prices hinder investor's ability to repay debts a collapse occurs. This can occur on a global scale or a country specific level. For a country when international investments flow into the country coupled with favorable economic growth this can lead to inflated asset and currency values. Once asset prices start deflating after a prolonged period of growth and the currency value is seen to move counter to policy objectives a sudden depreciation of the currency may occur. This can be due to policy objectives to keep the currency competitive for international trade or investors cashing out due to a change in market sentiment about a country's growth perspectives. In either case, the result is a decline in the currency's value. When liabilities are denominated in foreign currencies and assets are in a local currency, unexpected depreciations can deteriorate bank and corporate balance sheets. The foreign currency denominated liabilities further exacerbate loan repayment issues that can culminate in further loss in confidence. As debt becomes unmanageable, this 'currency induced Minsky moment' can result in a large and sometimes excessive depreciation of the country's currency. The continuous buildup of the currency's price during a tranquil economic period may result in an eventual sudden depreciation if the market perceives a possible crash. This build up in vulnerability can occur in any country and is not specific to any exchange rate regime. Looking at the range of exchange rate regimes the buildup of debt can wreak havoc on the economy when it is excessive and is coupled with a speculative market bubble. In a fixed rate system where the exchange rate is not allowed to fluctuate the underlying factor of the Minsky effect is still present. In this case a sudden crash would manifest in the governments frantic defense of the currency through reserve reduction or interest rate hikes.

According to Minsky's hypothesis longer periods of stability tend to lead to more speculations financed by excessively larger loans to cover investment positions. Applied to international cross-border financing, larger loans tend to come from abroad exposing companies to adverse movements of the domestic currency. According to Minsky: the longer a bullish period lasts, characterized by ever expanding credit, the more likely the crisis will occur. Additionally, the longer the tranquil period lasts the more investors forget the last crash which in turn leads to more risk taking. Putting this into the survival context, the longer a tranquil period prevails the more likely a currency crisis will occur.

All the above scenarios suggest that the longer a country experiences a period of calm in the currency market the higher the likeliness that a crisis is to occur. In the context of this study, we can say that the hazard function has a monotonically increasing shape because we expect the probability of a currency to undergo a large depreciation as time goes on. Therefore, this study tests for the possibility that the longer a country experiences a tranquil state in its currency market the more likely a currency crisis is to occur over time, which implies a monotonically increasing hazard function. This can be due to unsound lending practices, foreign denominated liabilities, firm' undercapitalized balance sheets and an overoptimistic market where investor have short time horizons and they only buy to sell. Alternative shapes of the hazard function would be either horizontal or downward sloping. A horizontal line would imply that time already spent in a tranquil state has not effect on the probability of a currency crisis and a downward sloping line could imply that these chances decline. Both cases were detailed above. There are theoretical underpinnings for all three cases however here only the case of a monotonically rising function is tested.

B. Variables Affecting the Hazard Function

B. 1. The Scope

Empirical literature has identified many potential variables linked with currency crises. Using the EMP as the tool to measure durations of tranquility in exchange rate movements, nine variables are evaluated to determine if they have significant effects on durations. Among the most important of these variables are the current account, direct investment, portfolio investment, IMF credit as percent of quota, real GDP growth, real effective exchange rate, unemployment, the LIBOR and the VIX. The current account, direct investment and portfolio investment are represented as a proportion of GDP. The idea is to choose indicators that were found to be significant in the signaling and Probit studies. Variables considered are from studies where: a. the indicators were utilized to measure the probability of a currency crisis; or b. the variables' pre- and post-crisis behavior were compared; or c. the variables' ability to signal a pending crisis in the future was significant and systematically measured. In the next section the rationale behind the inclusion of these variables is detailed.

B. 2. The Reasoning

In this section the included variables are explained along with their causal relationship with currency crises. The directional link is detailed, and the magnitude of the corresponding beta coefficient is hypothesized. The set of variables chosen is determined by the literature on early warning signals and prior studies on currency crises. Below, arguments are presents as to how the hypotheses are formulated. "Transparency here is emphasized so others may have a chance to see if they agree with the reasoning" (Willett, 2021, p. 20)

1. Current Account/GDP: In general, a country that undergoes depreciation in its currency experiences improved competitiveness in the domestic goods sector while the foreign goods sector becomes less competitive in the domestic market. If demand for exports and imports is relatively elastic this results in the improvement of the current account. When the country's current account is in deficit it can use external debt to finance the deficit so it can remain solvent. However, if the country is unable to cover the current debt with future revenue streams it may become insolvent. In this case, authorities may be more prone to allow the devaluation of the currency to improve the balance of payment account leading to a crisis in the currency market as measured by the EMP index. Additionally, when the country runs a deficit for an extended period investors/debtors may call into question the country's ability to pay for these liabilities leading to sales of domestic assets and further downward pressures on the currency culminating in a crisis. Capital flows, especially non-FDI flows are sometimes quite volatile and display large reversals so that a situation of a large current account deficit financed by capital inflows which are subject to reversals is especially vulnerable to crises (Willett & Srisorn, 2014). Thus, a higher level of current account deficit to GDP coupled with substantial real exchange rate appreciation can lead to higher chances of currency depreciation and a more likely currency crisis (Willett et al., 2004, p. 62) as indicated by the EMP index. In this context, a unit increase in the variable indicates that current account relative to GDP is now one percentage point higher. As the current account enters the dataset as a nominal positive amount, rather than a deficit measure, the above implies a beta smaller than one. A

higher level of current account deficit is hypothesized to increase probabilities of a currency crisis since it may be an indicator of balance of payments disequilibrium The relationship tends to be non-linear with small deficits, say 2 percent, not being an issue while large ones such as 5 or 6 percent are. Here both scenarios are assumed to affect the probability of a crisis in an equal proportion.

2. IMF Credit: The IMF credit system represents a credit mechanism that helps provide funds to countries that have transitory balance of payments problems. Under this facility, each country is allocated a quota that is determined by a formula that defines the relative position and size of each country in the world economy. The fund quota is determined in units of Special Drawing Right (SDRs). The value of SDR is a weighted average of a currency basket composed of five currencies as of 2021, however the value is quoted in USD by the IMF. Upon joining a country must pay 25 percent of the subscription in SDRs or other well accepted currencies (USD, EURO) and the rest in the member country's own currency. A country's quota, the maximum amount that it is obliged to contribute, determines its maximum allotment of SDRs. The higher the allotment the more a country can borrow relative to its quota contribution or relative to its position/size in the world economy. In the context of this study, 'IMF credit' implies a proportion of the country's IMF quota that is borrowed at a given time. On the one hand, investors can interpret a higher rate of IMF borrowing as a commitment to resolve balance of payments issues or a relaxed conditionality of borrowing. Both signal to investors that policymakers think long-term, or the Fund is moving the country into a lower risk category. On the other hand, when a country borrows a large amount relative to its GDP this can be taken as the country's inability to finance deficit through alternative forms of

financing, or its domestic credit market is deteriorating. Thus, it is hypothesized that a higher rate of IMF loan program may affect the probability of a currency crisis, but the direction of causality is not specified. The relationship can go either way. In essence, IMF borrowing could be interpreted that the program indicates that the problem is worse than had been thought or that the program would be sufficient to deal with the problem. Here the relationship is tested to gauge the relative importance of the above arguments. The above train of thought leads to a beta coefficient that is different from one. To clarify, a unit higher IMF credit shows a percentage point higher credit from the IMF relative to the country's quota.

3. Direct Investment: Foreign direct investment is comprised of longer-term purchases of business assets with the intention of continuing activities in a foreign country. The emphasis is on managing a foreign firm's operations actively. An increase in FDI would naturally increase the demand for domestic currency as more foreign investors demand money to purchase domestic currency denominated assets. This would result in an increase in the exchange rate. The EMP in this study defines a crisis as a downward pressure on the currency thus naturally a decrease in the FDI would register a crisis given a large enough decrease in magnitude. Given this, a lower FDI proportional to GDP can signal a currency crisis and thus a shorter duration in a period of currency tranquility. On the other hand, when FDI inflows are large relative to GDP this signals that a country has good prospects. Coupled with a current account, FDI tends to show a more stable source of capital inflows compared to bank lending or portfolio investments. Accordingly, the implied beta coefficient is smaller than one as a higher level of FDI is hypothesized to reduce the probability of a currency crisis in future periods. A unit

increase implies that direct investment relative to GDP is now one percentage point higher.

4. Portfolio Investment: This form of investment is mainly composed of new acquisition of stocks and bonds and the ownership of these does not involve active management. Portfolio investments are often held short term solely for financial gain. These investments can be characterized by sudden changes in direction given rapidly changing economic circumstances globally or in the country (Efremidze et al., 2016). Volatilities are most pronounced in bank flows where international lending institutions reallocate portfolios to safer assets, oftentimes positioned abroad, when conditions become more uncertain. Most bank flows are registered under portfolio flows as these institutions hold fixed income and equity investments abroad. Some however are recorded under direct investment that comprise of direct loans extended to counterparties. A higher level of portfolio investment in terms of GDP into a country can be an indicator that the currency is strong. This would be the implication in rational expectations models. On the other hand, behavioral finance suggests that the inflows can lead to excessive upward speculative pressure on asset prices. Given the extent of this overvaluation a sudden loss in the performance of these investments can result in abrupt sales of these assets, en masse, leading to a devaluation of the domestic currency. Portfolio inflows may imply that prospects of the country are promising thus the chance of a crisis is lower. However, a capital flow surge originating from portfolio flows can also lead to future vulnerabilities if the inflow reverses abruptly (Efremidze et al., 2017). In summary, if we believe in efficient market hypothesis than a portfolio inflow leads to a less likely currency crisis because investors believe there is a good outlook for the country. If we believe in the

behavioral approach of sudden surges/reversals than a big portfolio inflow leads to higher chances of reversals and currency crises. Therefore, the implied magnitude for the variable coefficient is different from one as the direction or causality is uncertain. Here, a unit increase shows that portfolio investment is one percentage point higher relative to GDP.

5. Real GDP Growth: Real GDP represents the inflation adjusted value of all goods and services produced in a country. Changes in real GDP can directly impact the value of the country's Forex rate. Starting from the Mundell-Fleming framework and the assumption that a country has a flexible exchange rate an increase in the growth of GDP can have varying effects on the domestic exchange rate. An increase in the GDP can come about for a myriad of reasons. However, the two major causes are monetary and fiscal policy. This uses the notion of Mundell-Fleming where there is excess capacity. Assuming the investment-saving [IS] and liquidity-money [LM] curves are in equilibrium along with the balance of payments [BP] an expansionary monetary or fiscal policy will have varying effects on the exchange rate. Depending on the level of capital mobility the BP schedule can be steeper or flatter. It can be shown that the higher the degree of capital mobility the flatter the BP curve. This is because for a given increase in GDP, which leads to a deterioration in the current account, a smaller increase in domestic interest rates is needed to induce capital inflows to ensure equilibrium. The opposite is true for low capital mobility. In an environment of reduced capital movement, an expansionary monetary of fiscal policy shifts either the IS or LM schedules to the right resulting in an interest rate that is below the required level that would ensure equilibrium in the balance of payments. This rate induces a capital outflow that pushes the BoP into deficit.

Expansionary monetary and fiscal policies also lead to higher output. These increase imports further leading to a deficit. A deficit means an excess supply of domestic currency that culminates is depreciation. Looking at the scenario when capital mobility is high and the BP curve is flat, an expansionary fiscal policy shifts the IS schedule to the right which can push interest rates above the point where the BoP would clear. This results in capital inflows that outweigh the increases in imports due to higher income levels. Thus, the balance of payments is in surplus. The consequence is an increased demand for domestic currency that leads to appreciation. Looking at the above examples we can see that increases in real GDP resulting from expansionary government policies can lead to depreciation or appreciation depending on the level of capital mobility. Thus, a hypothesis can be formed that a change in the real GDP growth affects the probability of a currency crisis however, the direction cannot be specified. This translates to a hypothesized beta that is different from one. For this variable input, a unit increase signifies a one percentage point higher GDP growth relative to previous year.

6. Real Effective Exchange Rate [REER]: REER is an indicator of the country's external competitiveness. It is a weighted average of the country's currency against a basket of currencies. It is adjusted for inflation differentials and is weighted by the respective trade weights. A less competitive trade sector can expect a smaller demand for its goods resulting in an eventual lower demand for the country's currency. A higher REER represents a lower competitiveness. When goods are more expensive, in relative terms, this lowers the quantity demanded for exports and the domestic currency and increases the quantity if imports. So, a higher level of real effective exchange rate can lead to a downward pressure on the currency potentially culminating in depreciation. As a result,

the hypothesized magnitude of the beta coefficient is larger than one. For REER, a one-unit higher value implies a one-unit higher REER compared to the previous year.

7. Unemployment: The unemployment rate is important as it often determines how policy will react to labor market conditions. When a government enacts expansionary policies, the intended result is typically lower unemployment and increased output. Using the notion of the Mundell-Fleming model [as explained above] expansionary fiscal or monetary policies can lead to an appreciation or depreciation of the domestic currency. The direction primarily depends on the degree of capital mobility. Therefore, when central authorities are faced with a higher-than-expected unemployment rate they may use expansionary policies to increase the number of employed, however a consequence is a change in the exchange rate. As the direction of change in the Forex depends on the factors highlighted above and can vary depending on the ease with which capital moves across the border the magnitude of causality between unemployment and exchange rates cannot be hypothesized. Therefore, in the model the beta of the unemployment variable is assumed to be different from one without any reference to magnitude. A unit increase in this variable represents a one percentage point higher unemployment level.
8. LIBOR: This rate is the money market lending rate (in the EURODOLLAR market) for banks and financial institutions around the world. It can generally be interpreted as the global short term interest rate level. Accordingly, a higher LIBOR rate generally implies a higher interest rate globally, which in turn affects capital flows. This can dilute a local government's attempt to raise domestic credit lending, leading to reduced economic activity, lower demand for domestic currency and a general capital flow to advanced economies that are perceived to be less risky. Thus, the implicit presumption is that an

increase in the LIBOR rate **level** results in a higher probability in currency devaluation. This relationship is represented by a beta coefficient that is larger than one. Here, a unit higher LIBOR shows a one percentage point higher international interest rates.

9. Volatility Index: The VIX follows stock market expectations of volatility based on S&P 500 index options. It is generally referred to as the 'fear index' of investors globally. While the VIX is based on expectations about the US stock market it has also been found to be a good indicator of risk perception across advanced economies. It gauges a 30-day forward looking volatility based on market prices of put and call options. A relatively high VIX generally indicates a late-stage expansion or conflict periods leading into global recession. A higher level of VIX can undercut local government attempts to keep the currency stable as investors rush to safe heaven currencies to avoid potential losses. Thus, a one-unit higher VIX level is assumed to lead to a downward pressure on the currency as gauged by the EMP. The implication is a Beta coefficient that is larger than one. In this context, a one-unit higher VIX signifies a one-unit absolute increase in the level of this index.

B. 3. Hypotheses

In all of the hypothesized variables the null hypothesis is that there is no effect of the variable on the conditional probability of a currency crisis.

1. H_α: $HR_{\text{Current Account/GDP}} < 1$. A higher Current Account relative to GDP negatively influences the conditional probability that a significant downward pressure on the currency will occur.

2. H_α: $HR_{\text{IMF Credit, Percent of Quota}} \neq 1$. The level of IMF borrowing relative to quota is hypothesized to lead to changing probabilities of a currency crisis however the net effect could go either way.

3. H_α: $HR_{\text{Direct Investment/GDP}} < 1$. Lower FDI flows proportional to GDP leads to a downward pressure on the currency and thus a shorter duration in a period of currency tranquility.

4. H_α: $HR_{\text{Portfolio Investment/GDP}} \neq 1$. Changes in the portfolio investment flow relative to GDP influences the probability of a currency crisis but the direction of causality is ambiguous.

5. H_α: $HR_{\text{Real GDP Growth}} \neq 1$. Varying real GDP growth leads to changing probabilities of a currency crisis. The directional effect is uncertain.

6. H_α: $HR_{\text{REER}} > 1$. Higher levels of REER result in a more likely downward pressure on the currency.

7. H_α: $HR_{\text{Unemloyment}} \neq 1$. An increase in unemployment results in a different probability of a currency crisis.

8.

H_α: $HR_{\text{LIBOR}} > 1$. A higher level of LIBOR positively affects the conditional probability that a significant downward pressure on the currency will occur.

9.

H_α: $HR_{\text{VIX}} > 1$. An increased level of VIX raises the conditional probability that a significant downward pressure on the domestic currency will take place.

B. 4. The Implications

The variables are hypothesized to have a proportional effect on the conditional probability of a downward pressure occurring on the currency in the future. This implies that when the HR coefficient is larger than one a one-unit increase in the variable is shown to increase the probability of a downward pressure on the currency in any quarter going forward. A beta larger than one, say 1.3, implies that as the covariate increases this affects the probability of the crisis positively and thus the conditional probability increases. A variable that increases by one unit is expected to raise the chance of crises by the magnitude of the Beta coefficient, which suggests a 30 percent higher probability in the above case. If the coefficient is less than one, let's say 0.5, than the probability decreases by 50 percent upon the coefficient increasing by one unit. Note, if the beta is close to zero this would imply that a one-unit higher covariate would reduce the chances of a crisis occurring to zero next quarter. If the beta is equal to one that any change in the variable has no effect on the probability of a currency crisis.

VIII. Results

This chapter details the results of this study. It is divided into two separate sections. First, hazard functions are presented using the Kaplan Meyer estimators for conditional failure probabilities over time. The curves in this section represent probabilities of a currency crisis in each quarter. Second, using the COX proportional hazard model, estimates or variable effects are demonstrated on the hazard functions in a country's exchange market.

This study utilizes the notion of Eichengreen (Eichengreen et al., 1996) when using the EMP index to gauge periods of downward pressure on the domestic currency. The index is composed of three components: exchange rate, reserves as a ratio of base money and interest rate. The first two components are expressed in percent changes and interest rate is represented as absolute changes since it is already in percentage terms. This notion follows Eichengreen's index formulation. Thus, all three components are expressed consistently in percent changes. A one percent change implies a 100-basis point increase in any of the three components.

$$EMP = \frac{1}{\sigma_{\%\Delta e}} \frac{\%\Delta e_t}{e_t} - \frac{1}{\sigma_{\%\Delta r}} \frac{\%\Delta r_t}{r_t} + \frac{1}{\sigma_{\Delta i}} \Delta i_t$$

Eq. 16 EMP with Weights

The weights used are precision weights to equalize the volatilities of the three components. It is important to note that the theoretically correct weights should be a function of relative elasticities in the foreign exchange market. However, these are not available for most countries. One alternative would be to use the 'principal of equal ignorance' and utilize equal weights. (Li et al., 2006). Equal weights can be used but that is left to future studies. In this study pressure on the currency is defined as outlier values of the index:

$$Crisis_t = 1 \text{ if } EMP > 1.5\sigma_{EMP} + u_{EMP}$$

= 0 otherwise

Eq. 17 Crisis Definition Restated

A pressure quarter is recorded when the EMP goes above its period mean by more than 1.5 standard deviations. For robustness tests this threshold is varied up to two and down to one standard deviations. In the literature these thresholds are varied from 1.5 (Eichengreen et al., 1996; Herrera & Garcia, 1999) to 3 (Kaminsky et al., 1998). The higher the EMP requirement for a crisis the less frequent the duration observation will be as a larger deviation from a mean trend signals a more severe pressure on the currency. Given this, the datasets with different threshold requirements still need to have a minimum of 20 observations [durations] for a statistically valid conclusion. Setting the threshold to 3 would result in less observations that the required minimum. Thus, the EMP magnitude is varied between one and two standard deviations. The tranquil period is counted between these periods of strong pressure on the currency. When two pressure periods are within two quarters of one another they are counted as one. This is the **exclusion window** that Eichengreen (1996) utilized in his study. In conducting robustness tests this exclusion window is varied from one to four quarters; two being the baseline reference output that Eichengreen used. Measuring the end of the pressure period may be cumbersome. One may argue that the immediate end of a currency crisis does not imply a tranquil period (Frankel and Saravelos). According to equations 12 and 13 when the exchange rates, reserves and interest rates stop deteriorating the **change** in these variables no longer signals a crisis episode. Therefore, the EMP index signals the end of a crisis when the components settle at a new level rather than on the level that prevailed before the crisis. However, when the exchange rate and reserves settle at a lower level and interest rates are high and unchanging this may not signal the end of a crisis. This may be addressed by leaving **a 'gap'**, between the end of the pressure period and the beginning of the tranquil period. In the model below the baseline is established at two quarters and varied from one to four quarters as robustness tests. In the data, the exclusion window and the 'gap' period are set to be equal and varied simultaneously for robustness checks.

A. Descriptive Statistics

The study utilized three-time intervals when running survival analysis on tranquility periods of floating exchange rate regimes. These three time periods were the post-recession 2009-2020 interval, the pre-recession 2000-2007 years and the cumulative 2000-2020 period. For each interval, the model was run with variables. In each of the three samples identical variables were included and compared if the direction and magnitude of the effects were similar on durations of tranquility in the exchange markets. The three different intervals were used to check for robustness in significance in variables.

As a reminder, a tranquility duration is conventionally defined as a continuous time period without a downward pressure on the currency (Eichengreen et al., 1996; Kaminsky et al., 1998). The **beginning** of a tranquil period commences when the EMP shows no more downward pressure on the currency. This manifests in the EMP ceasing to be below a specified standard deviation relative to its historical mean [for more details see: 'Measuring Duration of Tranquility' above]. At the other end, the tranquil period **concludes** when the EMP moves below the above-mentioned standard deviation threshold. So, a large downward move in the EMP index relative to mean signifies the **end** of the tranquil period. In sum, the downward pressure period is an outlier event as defined by the EMP index and the absence of it is defined as a tranquil state.

The definition of tranquility duration is slightly varied from the baseline that is described above. In this study a number of quarters are allowed to pass **after** the end of a [downward] currency pressure period before a new tranquil period is allowed to begin. This is called the exclusion-window in the model [detailed in ‘The Exclusion-window’ section in the main body]. It is varied between one and four quarters. So, a one-quarter exclusion-window implies that there is one quarter after the end of a downward pressure period before the tranquil period begins. The same applies to the two, three and four quarter exclusion-window scenarios.

It is important to point out that leaving an exclusion-window at the end of the crisis period shortens the duration of tranquility. This could be viewed as a bias down in the length of a tranquil period. However, this study focuses on the shape of the hazard function in general. If the above bias is introduced, it implies that the hazard function is shifted to the left by the length (in quarters) of the exclusion-window. However, this does not change the general shape of the hazard function itself. This is because the number of countries that experienced a certain length of tranquility up to a point is now tallied in the duration that is shorter than without the exclusion-window. To exemplify, let’s look at tallying the countries without the use of an exclusion-window. In this scenario there may be 60 percent of the countries that survived to 10 quarters and 40 percent of the countries that survived to 12 quarters without a downward pressure on the currency. Thus, the shape of the hazard function is downward sloping. Now, using the exclusion-window of two quarters the same scenario would yield 60 percent surviving to 8 quarters and 40 percent surviving to 10 quarters. Here the hazard curve still describes a downward sloping line, but it is shifted to the left by 2 quarters. Thus, differences in the shapes of the hazard functions would not exist when altering the exclusion-windows if there were no other assumptions about the definition of tranquility lengths. This is also true for tranquilities that are observed at the end of the sample period. The end of the sample period may cut off durations that is generally referred to as right-censoring in survival analysis. This occurs when tranquility still persists when the sample ends. This may be seen as a bias as well given durations may not have ended by the termination of the sample period. However, the assumption in survival analysis is that the time a country enters a tranquil period is independent of the duration of tranquility. Thus, the end of sample censoring is independent of tranquility duration and poses no problem to the analysis in the form of a bias. [for further explanation see: 'Duration, the Kaplan-Meyer Curve and the Survival Curve Graphs' section in the appendix]

Picking a sample period that includes more than just a few years introduces the model to potentially having multiple downward pressure periods for the same country. Without an exclusion-window when one downward pressure period ends the tranquility begins and the next downward pressure period does not start until the EMP diagnoses one. With the exclusion-window, it is possible that two downward pressure periods merge as a result of the tranquil period being not allowed to start before the next crisis downward movement begins. This would occur when two such downward pressures are closely grouped. In this scenario the lengths of the tranquil periods would not just simply shorten by the lengths of the exclusion-window. Rather, the lengths of these tranquil periods would change in character. Thus, the hazard functions may change in shape when varying the exclusion-windows from one to four. This is addressed and examined in the section below under Non-Parametric Estimation. Looking at the mean and standard deviation of tranquility durations one can draw a general picture of an average country's currency market. Examining the average duration of tranquility can aid in determining how long it takes on average to have a severe downward pressure on the currency. Given that **three distinct time intervals** are used in the study this can be done on three separate occasions.

Additionally, for each interval the exclusion-window can be varied to see if slightly different definitions change the mean and standard deviation of tranquility duration.

In Table 1 below the mean and standard deviations are listed for the different time periods and exclusion-windows along with a minimum and maximum duration of tranquility respectively. The time periods under consideration are the 2009-2020, the 2000-2007 and the whole sample of 2000-2020 periods. As the table below shows the average tranquility duration for the 2009-2020 years is 9.7 quarters and for the 2000-2007 years 14 quarters. The whole 2000-2020 observation interval has an average tranquility of 12.7 quarters. The period has an average expected tranquil period duration of 12.7 quarters. Considering the associated standard deviations of approximately 6, 11 and 8 for the respective periods the general distribution is widely scattered. Thus, there is no close clustering of durations around the mean in any of the above mentioned three distinct periods.

Further examining the moments, the wide scattering of durations imply that countries are not clustered thus the occurrence of failure is not characteristic of a particular range of duration. The minimum and maximum durations differ between the observation periods as the length of these sample periods are **not** equal. Even though observation periods are not equal in length, in a longer observation sample one may expect to see equal means and standard deviations **if** the distribution of durations are equal across time. However, this is not the case. In the 2000-2007 period the maximum length of tranquility is 37 and the mean and standard deviations are larger compared to the other two samples. This implies that in the 2000-2007 case countries experienced longer tranquil periods. This however does not indicate that the number of currency crises were different in numbers. It only shows that the average durations of tranquility are longer and more persistent compared to the other sample periods. The difference may be due to smaller downward pressures in the 2000-2007 interval that are not registered in the EMP index as downward pressure periods. Thus, tranquilities are not ‘interrupted’ by such episodes and so persist for longer durations. The 2009-2020 period has lower mean tranquility durations compared to the other samples. The mean is 9.7 quarters. This can be indicative of more uncertainty in currency markets. More uncertainty can result in a higher number of downward pressure episodes culminating in shorter tranquility periods.

As the three sample lengths are different the comparison of the means and standard deviations are difficult across these intervals. The comparison is meaningful mainly across differing exclusion-windows in the same sample. This is because a downward pressure is measured relative to the mean of the sample. One sample may diagnose a pressure period more often because the mean and standard deviation is smaller and outlier occurrences may be observed more often. Looking at the varying exclusion-windows in each time interval one can observe that the average duration decreases as the exclusion-windows increase. This is a necessary result as the longer one waits before the beginning of a tranquil interval the shorter one can expect the tranquility to last before another downward pressure episode.

Observing the 2009-2020 interval the average duration decreases from 10.21 to 9.18 quarters as the exclusion-windows increase. This is due to the shortening of durations because there is more time allowed to pass after a downward pressure period before the new tranquility is ‘allowed’ to begin. Standard deviations [with each quarter increase, from one to four] do not change much. Thus, the expected proportion of countries with durations above or below the mean stay approximately the same. As the exclusion-window increases the standard deviation is approximately equal along with the above mentioned lower mean durations. So, within the sample of 2009-2020 the dispersion of durations stay the same regardless of the exclusion-window used. This could mean that all durations equally shorten by the number of exclusion quarters. The difference in standard deviations would be discernible if a large number of countries would have more than one tranquility episodes. This would imply that there are at least two downward pressure periods for those countries. If the exclusion-window is higher this may merger two downward pressure period and thus shorten tranquilities. So, varying the number of exclusion quarters do not change expected durations because most countries have only one tranquil duration in the sample.

Observing the other two-time samples, the same conclusions can be drawn for the mean and standard deviation moments. Increasing the exclusion-windows for the 2000-2007 and the 2000-2020 periods do not change the expected proportion of countries with lower or higher tranquility durations because the standard deviation stays approximately the same. However, as before, the expected durations shorten as more time is allowed to pass before the beginning of the tranquil duration.

1.5 STANDARD DEVIATION EMP INDEX					
	Exclusion Window:	Tranquility Duration, **Mean**:	Tranquility Duration, **Standard Deviation**:	Tranquility Duration, **Minimum**:	Tranquility Duration, **Maximum**:
2009q3-2020q2:	1 quarter	10.21	6.27	1	23
	2 quarters	9.73	6.25	1	23
	3 quarters	9.73	6.25	1	23
	4 quarters	9.18	6.35	1	23
Average:		**9.7125**	**6.28**	**1**	**23**
2000q1-2007q3:	1 quarter	14.74	11.73	1	37
	2 quarters	14.29	11.68	1	37
	3 quarters	13.84	11.66	1	37
	4 quarters	13.38	11.66	1	37
Average:		**14.0625**	**11.6825**	**1**	**37**
2000q1-2020q2:	1 quarter	13.17	8.24	1	36
	2 quarters	12.91	8.26	1	36
	3 quarters	12.65	8.31	1	36
	4 quarters	12.1	8.43	1	36
Average:		**12.7075**	**8.31**	**1**	**36**

Table 1. Descriptive statistics.

B. Non-Parametric Estimation

As the model describes probabilities of failure, crisis hazard functions can be drawn based on these estimates. In the context of this study probabilities represent chances of currency crises and/or crashes in each quarter. In essence, the hazard curve shows the probability of a crisis every quarter. As survival analysis looks at differing quarters going forward, these probabilities differ for different quarters. Thus, a curve is different from a horizontal line as this would imply that these probabilities are all the same for all quarters in the future. A crisis occurs when there is a downward pressure on the currency as defined by the EMP index and crises occur when the downward pressure on the exchange rate materializes. Thus, currency crashes are a sub-category of crises.

In Figure 1 three hazard functions are presented. The three curves represent three time periods, namely the pre-recession period of 2000-2007, the post-recession from 2009 to 2020 and the cumulative study period that spans the two decades starting in the year 2000. All three graphs show a generally upward sloping curve with a slight break in the trend around the middle of the sample period. This can imply that initially as time passes the probability of a currency crisis increases. Prior to this phase the currency either just switched from a different regime to a floating system or has just experienced a crisis. Thus, this is the time when new government policy is tested to see the resilience of the currency. Following this a general adjustment phase is seen that's characterized by a transitory period when the country's currency is less likely to undergo a crisis. Here, the value of the currency is perhaps seen as the result of a successful policy for balancing internal and external economic goals. In the final phase, observing a sustainable currency policy, government and private venture interests may start to relax due diligence. This can be manifested in higher levels of borrowing in foreign denominated debt, more speculation on asset values, less restrictions on capital account flows and an overvalued currency. A large public and private sector borrowing requirement eventually can lead to a ballooning public debt and investor concerns (Sachs et al., 1996) . In general, an economic cycle is driven by overly optimistic speculation that defines a bullish period that typically is followed by a market collapse. When international capital flows into the country is coupled with favorable growth patterns and this can lead to inflated asset and currency values. When assets prices start to decline due to inconsistent mental models on the state of the economy or excessive focus on the short run gains (Willett & Srisorn, 2014) investors are quick to withdraw funds through portfolio flows or suffer the loses if the investments were in long-term ownership represented by direct investments. When liabilities are denominated in foreign currencies, but assets are priced in domestic currency an unexpected depreciation deteriorates bank, corporate as well as government balance sheets. The result is a reversal in investments culminating in a currency crisis. A longer period of stability tends to cause more speculation and lax policies. The speculation is financed by ever increasing loans from abroad leading to higher leverage ratios and undercapitalized firms with large liabilities. When gains in asset prices no longer cover the interest in liability positions a reversal occurs leading to mass exodus and a crisis in the currency. The longer a bullish period lasts, characterized by ever expanding credit, the more likely the crisis will occur. Putting this into the survival context, the longer a tranquil period prevails the more likely a currency crisis will occur. Reciting the assumption: this study hypothesizes that the effect of over borrowing in international markets and an asset liability currency mismatch leads to an ever-increasing probability of a currency crisis.

In assessing the hypothesis three periods are examined. These are: the 2000-2007 pre-recession period, the post-recession of 2009-2020 and the aggregate study of 2000-2020. Looking at Figure 1 a general upward trend in the probability of a crisis in each period is observed in all hazard graphs. This suggests that the hypothesized shape of the hazard function is supported. The more a country spends in a tranquil period the more likely that it will undergo a crisis in its currency. This applies to all periods tested. Both pre- and post-recession samples as well as the cumulative graph that spans the entire sample period show confirmation to this. It is important to emphasize that the crises here are defined by a 1.5 standard deviation outlier move in the EMP index. Also, two crises are considered one if they are within two quarters of one another. Robustness tests to check validity of the above conclusion is undertaken in the next section.

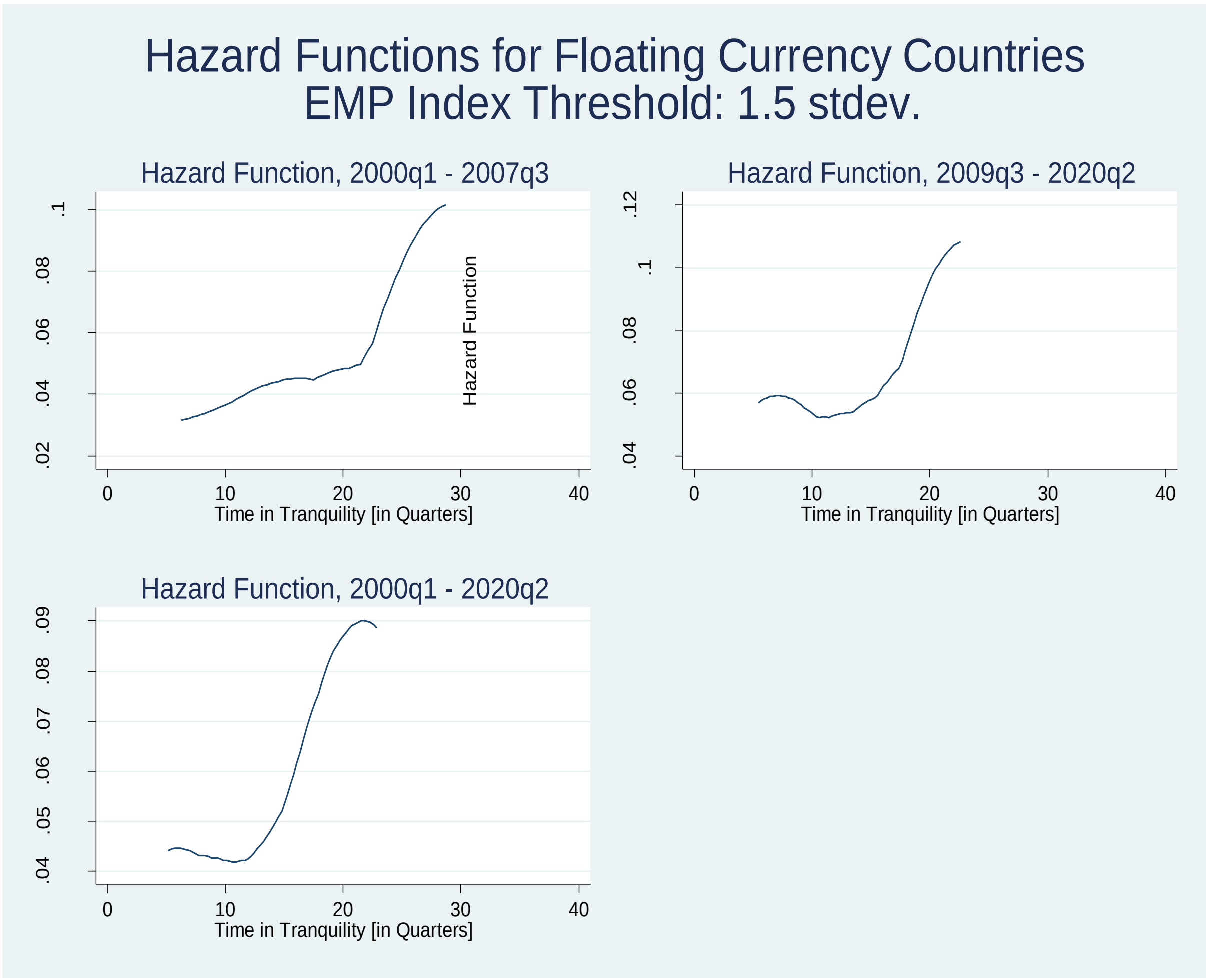


Figure 1. Hazard Functions, 1.5 Standard Deviation Threshold, Two Quarter Exclusion Window

Upon further examination of Figure 1 the hazard graphs show a sudden jump in the probabilities of crises from around 0.04 to about 0.1. All three graphs show this approximate numerical jump. This is more than a twofold increase in the magnitude of crisis probability. Consequently, the hazard curves clearly show that a country has a much higher chance of falling into a currency crisis after a longer time period of **not** having a 'failure' in the currency market. Thus, an average country is much more likely to have a period of calm at the beginning of the tranquil period than after a longer period. The general distribution of durations in the descriptive statistics section indicated a widely scattered duration range around the mean. Clustering of crises are not observed in any time periods. Thus, a contagion-based currency crisis cannot be implied in this sample of developing countries as large number countries do not experience a frenzy of devaluation pressures after a specific quarter of tranquility. The hazard functions strictly show conditional failures and clustering of failures would indicate non-conditional failure occurrence.

Looking at Figure 1 it is apparent that the hazard functions do not start at time zero on the horizontal axes. This is because the hazard graphs are smoothed to give continuous lines. The smoothing technique is beyond the scope of this explanation. However, to give a simple example we can assume that the individual conditional probability datapoints are smoothed using the moving average [MA] technique. When utilizing the MA method there are generally a few observation points that are lost to the averaging process, both at the beginning and the end of the observation range. Like the MA procedure the smoothing technique used in survival analysis also loses a few observations at both ends to arrive at a continuous line graph. Thus, the lines in Figure 1 depict general trends rather than individual observation points for conditional probabilities of failure through time.

As pointed out in the section on crisis identification, the literature uses an exclusion window after the last identified crisis before a tranquil period is registered. If there is another crisis in that tolerance window it is considered the same crisis. The baseline assumption until now was that two crises are one if they occur within two quarters of one another. To test the model further for robustness the exclusion window below is varied between one and four quarters for all three time periods.

Figure 2 presents the 2000-2007 period. The curve that shows ‘2 quarters’ is the same as is Figure 1 for the same pre-recession interval. Looking at the graphs, it is apparent that the shape of the curve does not change much. This further supports the notion that we can expect an even increasing probability of a currency crisis in the sample of countries.

To continue testing for robustness the 2009-2020 period hazard graphs are drawn with similarly varying the exclusion window. This is shown in Figure 3.

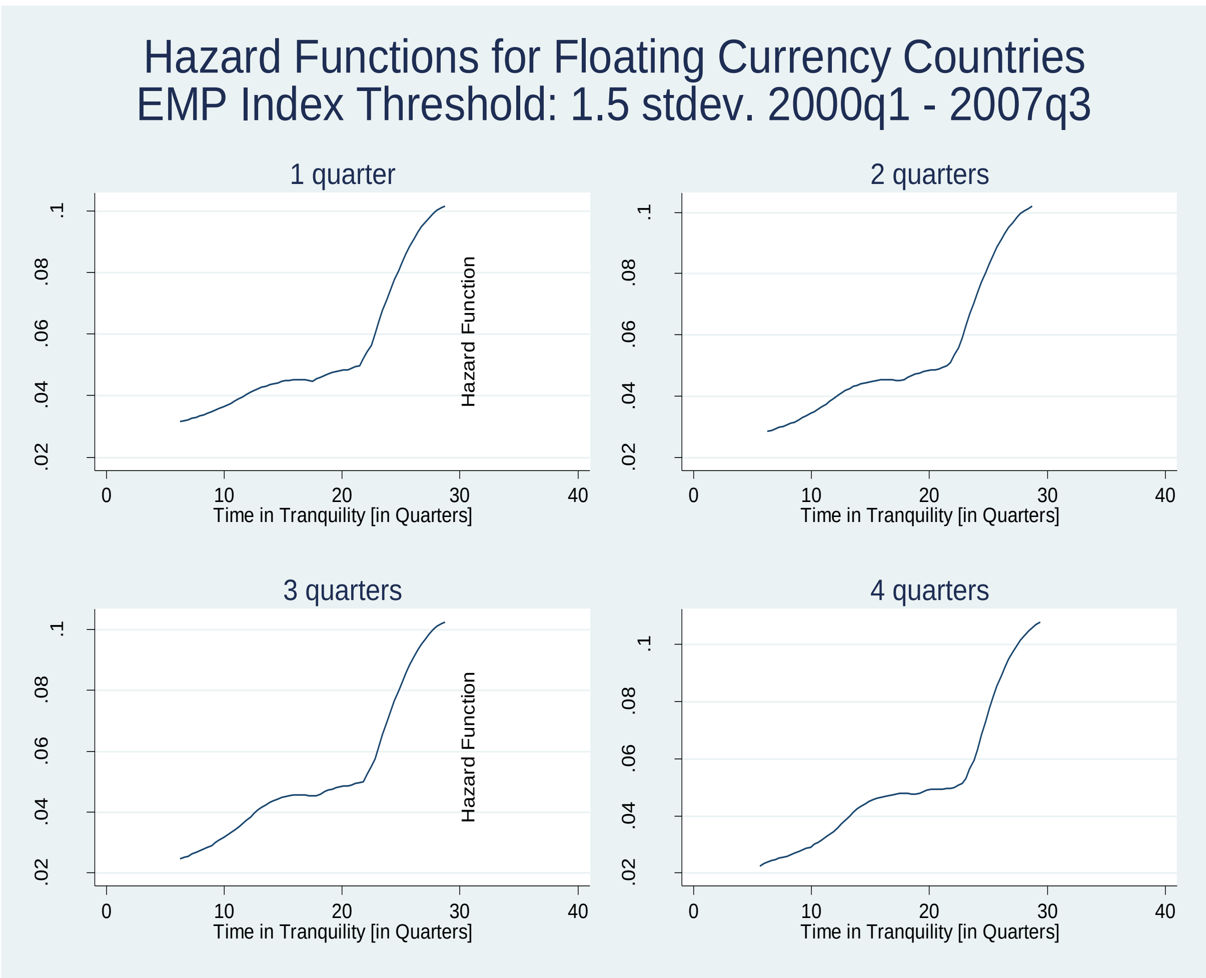


Figure 2. Hazard Functions, 2000-2007 Period, 1.5 Standard Deviation Threshold, Varying Exclusion Window

The first graph on the left suggests that as time progresses the probability that a country will experience a pressure on its currency increases. However, this upward trend is not monotonic. The probability levels off temporarily between the quarters of approximately eight and eighteen before increasing again. In the leveling off, the currency is perhaps seen as a successful policy for balancing internal and external economic goals. However, observing a sustainable currency policy, government and private venture interests may start to relax due diligence. This may be in the form of more borrowing in foreign denominated debt, more speculation on asset values, a swift liberalization in the capital account and an overvalued currency.

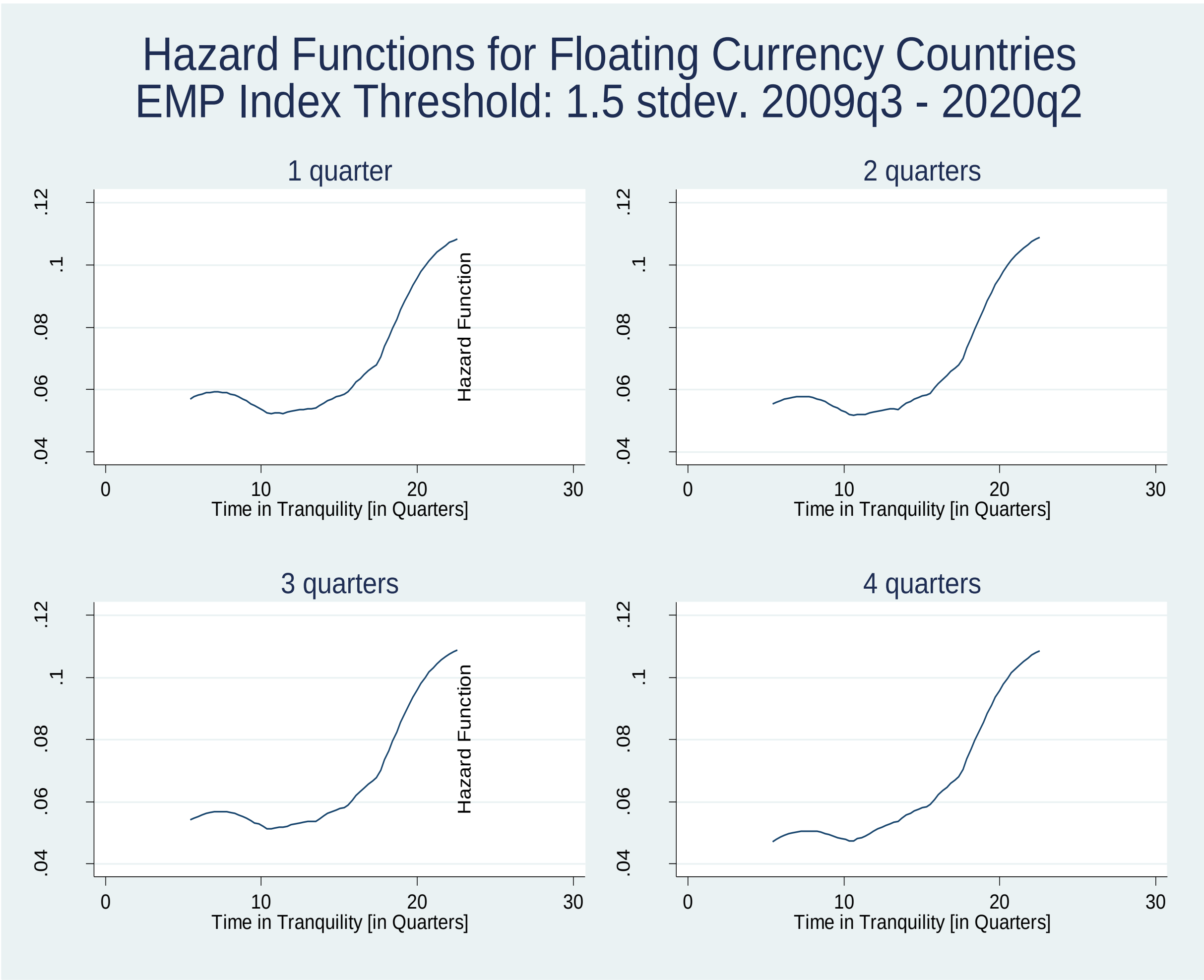


Figure 3. Hazard Functions, 2009-2020 Period, 1.5 Standard Deviation Threshold, Varying Exclusion Window

This establishes an ever-higher probability of a crisis in the remaining time in tranquility. Examining the trend, the hypothesized effects still hold and a general upward trend in crisis probability is still observed.

To further test for robustness in time dependence the whole period of 2000-2020 is used to draw the hazard curves. This is undertaken in Figure 4. The curves closely resemble the 2009-2020 trends shown in Figure 3. In all robustness tests above, the exclusion window here is altered between one and four quarters.

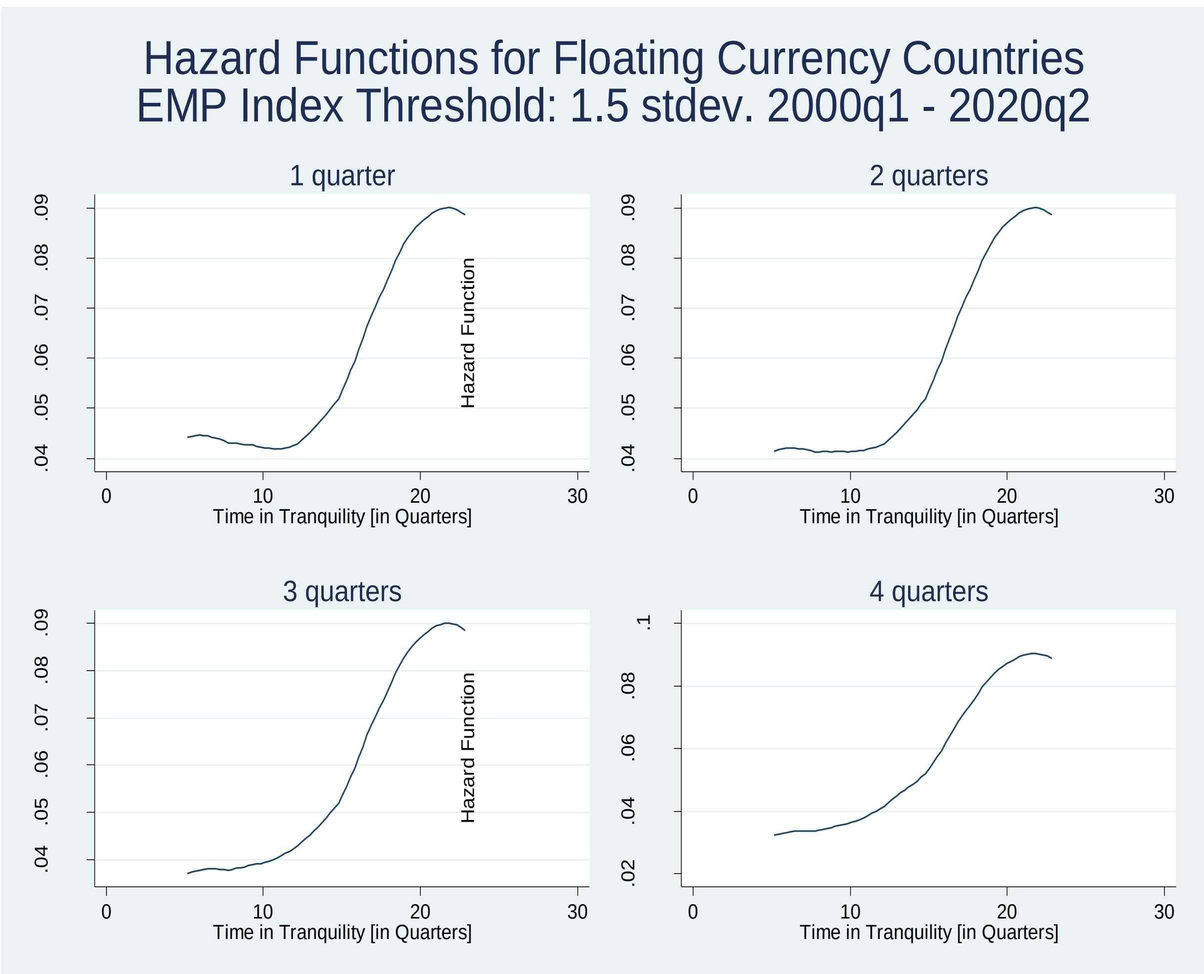


Figure 4. Hazard Functions, 2000-2020 Period, 1.5 Standard Deviation Threshold, Varying Exclusion Window

In the above four graphs it is shown that the probability of a currency crisis is stable in the first ten quarters of tranquility. This is followed by a generally upward sloping crisis probability for the rest of the observation period. The explanation follows the one in the above case where an eventual buildup of debt, trade, and capital account policies lead to a crisis in the country's forex market. This further supports the notion that the longer a country spends in a tranquil period the more likely that a currency crisis will occur. This supports the notion that "there is considerable evidence […] [that] in good times memories of previous crises begin to fade and complacency and underestimation of risk set in" (Willett, 2021, p. 28) leading eventually to a crisis.

C. Semi-Parametric Estimation

The hazard curve can uncover important information about the evolution of crisis probability. The non-parametric section above has looked at the general shape of the hazard functions and drew conclusions about the time dimension factor on tranquility. The non-parametric estimation in general shows an upward sloping relationship between time and the probability of exiting a tranquil period in the currency market. Up to now variable effects on the hazard function were not considered. In this section impacts of economic and financial variables are included to gauge effects on the hazard curve. This translates into variables shifting the curve up or down depending on the direction of causality. Generalized variable effect across countries are assumed using the notion of Munchau. He notes that “one of the biggest surprises one realizes when studying financial crises across countries and time is how similar they are” (Munchau, 2009, p. 11). To reiterate, the hazard curve shows probabilities of currency crises **in** a given quarter. This should not be confused with cumulative probabilities that show the chances of a crisis **by** a given quarter. In this study domestic and international variables are tested to ascertain the effects on the hazard functions of exiting from a tranquil period. The covariates are: Current Account, IMF Credit as a percent of country quota, Direct Investment, Portfolio Investment, Real GDP Growth, Real Effective Exchange Rate, Unemployment, the 3-month LIBOR average and the 3-month VIX average. [for further explanation see variables included in the study, in the Appendix]. Current account, direct investment and portfolio investment are included as a percentage of GDP to facilitate comparability across countries and time.

C. 1. Survival Analysis

Table 2. below shows four regression results for the post-recession 2009-2020 period. The EMP crisis measure threshold is 1.5 standard deviation. Model 2 in the table represents the baseline regression that uses the 2-quarter exclusion window. This implies that if two crises are within two quarters of one another they are considered the same crisis. Using Model 2 as a starting point four variables are found to be statistically significant. These variables are the current account, real GDP growth, Real Effective Exchange Rate [REER] and unemployment. The current account coefficient is consistent with the hypothesized value of less than one. Looking at Model 2, the hazard ratio for this variable is 0.938. This implies that a one percentage point higher current account relative to GDP causes the ratio of crisis probabilities to equal 0.938. Thus, when the Current Account/GDP ratio increases by one percentage point the probability of a crisis occurring in any future period decreases by 6.2 percent [0.938 - 1]. Looking at the deficit side, this also suggests that when a similar one percent increase in deficit is observed the crisis probability increases by the same 6.2 percent. It is important to point out that the current account represents surplus and/or deficit. A positive current account value is a surplus and a negative value is a deficit. Thus, a one percentage point higher current account to GDP ratio can imply a smaller deficit or a larger surplus. If the hazard probability of a crisis occurring in a given period is 20 percent than a one percentage point higher current account to GDP ratio decreases the hazard to 18.76 percent [20*0.938], a 6.2 percent decrease. It is important to emphasize here that it is a probability that decreases by a certain percent. Following this logic, looking at real GDP growth, a one percentage point higher GDP growth rate raises the chances of a currency crisis occurring by 5.7 percent [1.057 - 1]. The beta coefficient was assumed to be different from one which is consistent with the hypothesis. If the hazard probability of a crisis in

a given period is again 20 percent than we can expect a one percentage point higher real GDP growth to lead to a crisis probability of 21.14 percent [20*1.057]. This is a 5.7 percent increase. In the baseline model real effective exchange rate also showed significance. The Beta coefficient matches the hypothesized value. The assumption is that a one-unit increase in the REER leads to a higher crisis probability. According to the model output, a one-unit higher REER leads to a 7.9 percent higher chance that a currency crisis will occur in any future period [1.079 - 1]. This means that as the economy's trade competitiveness chips away represented by a higher level of REER the chances of a currency crisis increase proportionally. The final significant variable in Model 2 is unemployment. The hypothesized magnitude of the Beta is a value that's different from one. The coefficient of 0.773 shows that when the unemployment increases by one percentage point the probability of a crisis occurring in the future decreases by 22.7 percent [1-0.773]. So, when the hazard probability in a quarter is 20 percent than a one percentage point higher unemployment decreases the probability of a currency crisis in that quarter by 22.7 percent to 15.46 percent.

Taking advantage of the ability to vary the exclusion window and gap between the end of the crisis period and tranquil period, robustness tests are carried out in Table 2. As a reminder, the exclusion window considers two pressure periods on the currency as one if they are within x quarters. The 'gap' leaves out a period between the end of the pressure period and the beginning of the tranquil period so the EMP component variables can settle at the new norm before a new tranquil period can be registered.

C. 1. 1. Robustness Tests:

In Table 2 the exclusion window and 'gap' is varied between one and four quarters, that are represented by Model 1 to 4 in the same order. The baseline model with an exclusion window of two, used by Eichengreen (Eichengreen et al., 1996) and (Herrera & Garcia, 1999), is represented by Model 2 in the table. Looking at variations from Model 1 to 4 the covariates that show robust significance in most cases are: the current account as a portion of GDP, real GDP growth, real effective exchange rate and unemployment. These are all shown to have the same approximate magnitude and directional influence across different models. The effects of these were detailed above.

Looking at all models in Table 2 we can see that a one percentage point increase in the current account and unemployment lowers the probability of a currency crisis in the future and an equal magnitude increase in real GDP growth and real effective exchange rate increases this probability. Different studies on currency crises have emphasized the slowdown in exports as an important contributor to currency volatility (Tudela). Also, before a crisis the current account typically moves into deficit. This is confirmed by a beta less than one for the current account factor. A higher growth in real GDP causes an increase in probability of a crisis. This could be due to the growth generating buoyancy in the domestic asset market attracting capital inflows initially followed by a decline when there is a slowdown in asset price return. This causes depreciation, reversals of capital flows and a possible currency crisis. Real effective exchange rate has shown consistent robustness in the models. An increase in the REER level suggests an increased probability in a currency crisis. REER is a proxy for international price competitiveness and forex misalignment. Deteriorated competitiveness lowers exports relative

EMP Index Threshold: 1.5 stdev., TIME PERIOD: 2009q3-2020q2

	Hypotheses	Model 1	Model 2	Model 3	Model 4
Current Account/GDP	ß<1	0.951*	0.938**	0.938**	0.934*
		(0.077)	(0.043)	(0.043)	(0.080)
IMF Credit [% of Quota]	ß not=1	1.001	1.002	1.002	1.002
		(0.149)	(0.113)	(0.113)	(0.176)
Direct Investment/GDP	ß<1	0.378	0.440	0.440	0.259
		(0.106)	(0.184)	(0.184)	(0.103)
Portf. Investment/GDP	ß not=1	0.618	0.574	0.574	0.591
		(0.107)	(0.125)	(0.125)	(0.107)
Real GDP Growth	ß not=1	1.045*	1.057*	1.057*	1.070
		(0.079)	(0.055)	(0.055)	(0.102)
REER	ß>1	1.084*	1.079*	1.079*	1.179**
		(0.059)	(0.084)	(0.084)	(0.027)
Unemployment	ß not=1	0.791**	0.773**	0.773**	0.724**
		(0.034)	(0.032)	(0.032)	(0.038)
3-mo. LIBOR	ß>1	0.679	1.223	1.223	1.107
		(0.743)	(0.857)	(0.857)	(0.931)
CBOE VIX	ß>1	0.987	0.956	0.956	0.963
		(0.846)	(0.553)	(0.553)	(0.704)
Observations		28	26	26	24
AIC		80.20	67.91	67.91	51.76
BIC		92.19	79.24	79.24	62.37

Exponentiated coefficients; p-values in parentheses
1.5 Stdev.: Model 1: 1 quarter, Model 2: 2 quarters, Model 3: 3 quarters, Model 4: 4 quarters
* p<0.10, ** p<0.05, *** p<0.01

Table 2. EMP Index Threshold, 1.5 Standard Deviation, 2009 – 2020.

to import culminating in lower domestic currency values, which can result in a crisis if the effect is strong enough. Glick (Glick & Hutchison, 2013) found that in the years before a currency crisis the REER typically shows evidence of overvaluation. In Table 2 the models suggest that a higher unemployment lowers the vulnerability to crises. This is contrary to views often expressed in the economic literature but is consistent with a standard Mundell-Fleming model with high capital mobility. In general, economic slowdown mirrored by a rise in unemployment can be a driving force behind government actions to be more attentive to domestic objectives. This typically causes the CB to undertake expansionary monetary policy which may lead to depreciation. However, this devaluation occurs in fixed regimes or in instances where the exchange rate is managed. In a floating regime arrangement, a rise in unemployment without any intervention from government can result in an appreciated rather than a depreciated currency. When capital mobility is high and the BP curve is flat, in the Mundell-Flemming model, an expansionary fiscal policy shifts the IS schedule to the right. This can push interest rates above the point where the BoP would clear. This results in capital inflows that outweigh the increases in imports due to higher income levels. Thus, the balance of payments is in surplus. The consequence is an increased demand for domestic currency that leads to appreciation. In Table 2 the time period used is the post-recession 2009-2020 period. Given recent trends in globalization and the move towards opening up economies, liberalization of trade and the capital account may account for higher capital mobility. This can lead to a flatter BP schedule in general for countries included in the sample. Thus, a higher level of unemployment coupled with expansionary fiscal policies and a flat BP curve can result in currency appreciation and a lower probability of a crisis. Monetary policy would cause an opposite reaction in the currency's value however here that does not seem to be the case.

For comparison the same study is run using the pre-recession 2000 – 2007 period. The result is shown in Table 3. In general, four variables have shown significance: the current account, direct and portfolio investment, and real GDP growth. The current account is opposite the expected magnitude. This means that the direction of causality is not consistent across time periods for this variable. Here, a one percentage point higher current account to GDP results in higher probabilities of a currency crisis; shown by a beta of larger than one. Direct investment is shown to have an inverse say negative relationship with crisis probability. Looking at Model 5, a one percentage point higher direct investment to GDP leads to a 43.1 [1-.569] percent decrease in probability of a currency crisis. In (Kumar et al., 1998) a set of emerging countries have yielded similar results. FDI is a safer way to finance investments. It is directly related to investments in infrastructure. Thus, a higher level or direct investment signals a safer prospect of the country. As FDIs cannot be liquidated quickly an increase in this variable signal long-term commitments of investors. Thus, higher FDI inflows suggest a safer economic environment and consequently a lower probability of a currency crisis. In Table 3 portfolio investment also shows significance. As the beta is larger than one this implies than a larger inflow increases the chances of a crisis. Real GDP growth has the same magnitude as in Table 3. The inference is the same as before. Unemployment also shows up but only in one regression suggesting that the variable is not robust in all cases.

Applying the same technique to the whole period of 2000 -2020 a somewhat different picture emerges. In Table 4 only two variables consistently show significance: the LIBOR and VIX. The regressions suggest that a one percentage point higher LIBOR in Model 9 increases the probability of the currency crisis by 28.1 percent [1.281 – 1]. A one-unit increase in the VIX results in a 11.8 [0.882 – 1] percent decrease in the same probability. Real GDP growth and unemployment also show some significance with the same directional causality as in the above cases.

EMP Index Threshold: 1.5 stdev., TIME PERIOD: 2000q1-2007q3

	Hypotheses	Model 5	Model 6	Model 7	Model 8
Current Account/GDP	ß<1	1.065*	1.062*	1.066	1.129**
		(0.076)	(0.094)	(0.121)	(0.022)
IMF Credit [% of Quota]	ß not=1	1.000	1.002	1.001	1.009
		(0.929)	(0.722)	(0.853)	(0.326)
Direct Investment/GDP	ß<1	0.569**	0.705	0.864	0.322**
		(0.036)	(0.376)	(0.750)	(0.042)
Portf. Investment/GDP	ß not=1	1.836**	1.468	1.120	3.538**
		(0.036)	(0.374)	(0.843)	(0.034)
Real GDP Growth	ß not=1	1.166**	1.130*	1.085	1.227*
		(0.013)	(0.074)	(0.247)	(0.057)
REER	ß>1	1.007	1.014	1.007	0.994
		(0.739)	(0.559)	(0.814)	(0.832)
Unemployment	ß not=1	0.887**	0.914	0.943	0.872
		(0.043)	(0.210)	(0.454)	(0.144)
3-mo. LIBOR	ß>1	1.258	1.149	1.088	1.226
		(0.233)	(0.562)	(0.739)	(0.414)
CBOE VIX	ß>1	1.018	1.002	0.958	0.820
		(0.855)	(0.980)	(0.694)	(0.202)
Observations		26	25	24	23
AIC		74.11	70.87	66.32	53.18
BIC		85.44	81.84	76.92	63.40

Exponentiated coefficients; p-values in parentheses

1.5 Stdev.: Model 5: 1 quarter, Model 6: 2 quarters, Model 7: 3 quarters, Model 8: 4 quarters

* p<0.10, ** p<0.05, *** p<0.01

Table 3. EMP Index Threshold, 1.5 Standard Deviations, 2000 – 2007.

EMP Index Threshold: 1.5 stdev., TIME PERIOD: 2000q1-2020q2

	Hypotheses	Model 9	Model 10	Model 11	Model 12
Current Account/GDP	ß<1	0.976	0.978	0.969	0.969
		(0.337)	(0.432)	(0.293)	(0.308)
IMF Credit [% of Quota]	ß not=1	1.001	1.002	1.002	1.002
		(0.251)	(0.120)	(0.129)	(0.122)
Direct Investment/GDP	ß<1	1.094	1.324	1.251	1.223
		(0.558)	(0.143)	(0.258)	(0.316)
Portf. Investment/GDP	ß not=1	1.024	0.809	0.961	0.965
		(0.877)	(0.329)	(0.852)	(0.866)
Real GDP Growth	ß not=1	1.038	1.029	1.052*	1.053*
		(0.102)	(0.235)	(0.065)	(0.068)
REER	ß>1	0.995	1.010	1.003	0.999
		(0.781)	(0.599)	(0.902)	(0.978)
Unemployment	ß not=1	0.895	0.933	0.854**	0.858**
		(0.104)	(0.293)	(0.037)	(0.049)
3-mo. LIBOR	ß>1	1.281*	1.264	1.325*	1.320*
		(0.084)	(0.114)	(0.075)	(0.085)
CBOE VIX	ß>1	0.882**	0.857**	0.821**	0.838**
		(0.043)	(0.029)	(0.012)	(0.029)
Observations		39	37	36	35
AIC		140.9	124.0	111.6	106.0
BIC		155.9	138.5	125.8	120.0

Exponentiated coefficients; p-values in parentheses

1.5 Stdev.: Model 9: 1 quarter, Model 10: 2 quarters, Model 11: 3 quarters, Model 12: 4 quarters

* p<0.10, ** p<0.05, *** p<0.01

Table 4. EMP Index Threshold, 1.5 Standard Deviations, 2000 – 2020.

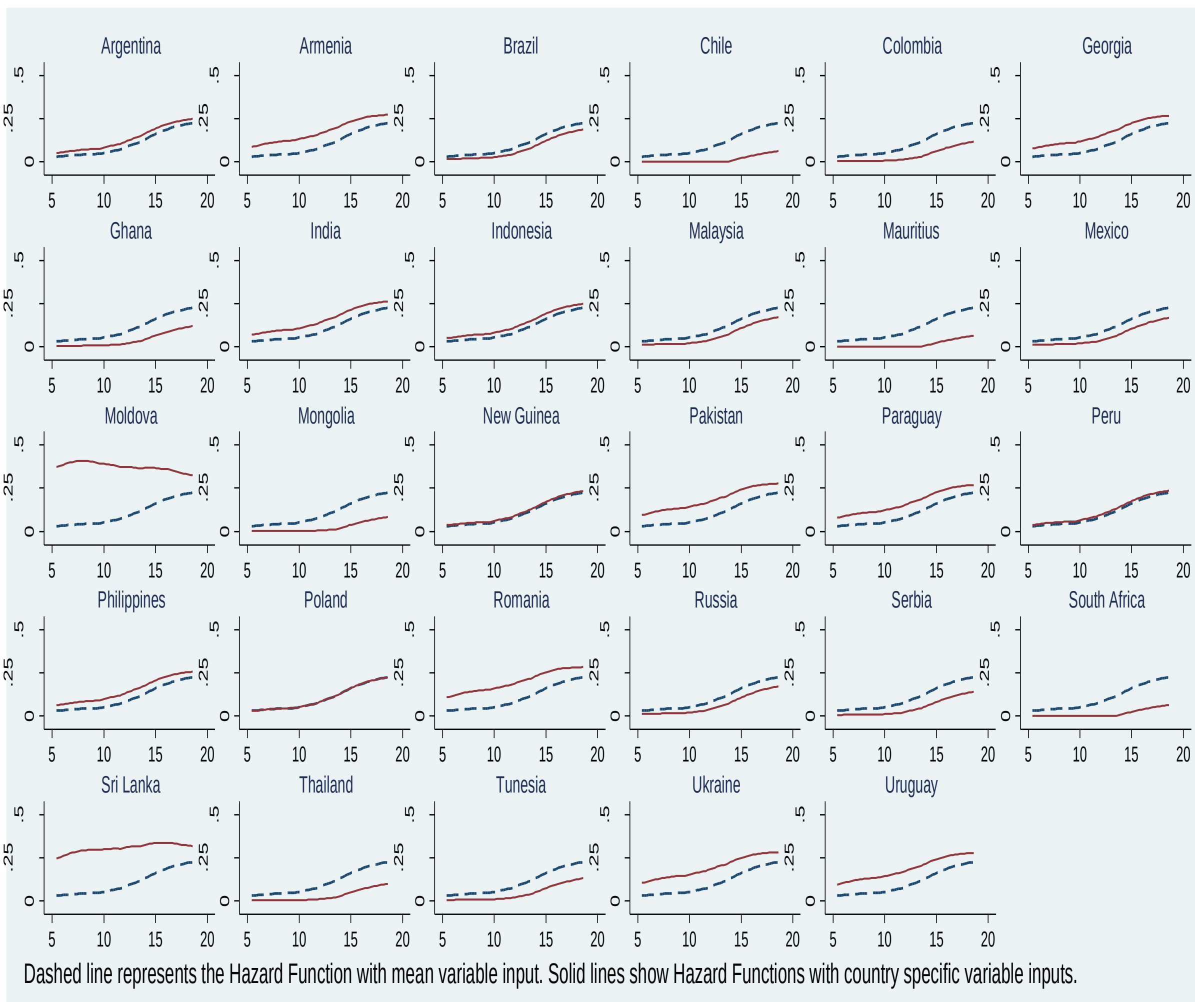
In Table 5 all twelve regressions are summarized. The Table shows significant variables in each regression in bold along with the level of significance. Real GDP growth and unemployment show up in all three time periods with robustness. Additionally, the significant betas are the right magnitudes for these two variables. This shows that a one percentage point increase in real GDP generally increases the probability of a currency crisis across all periods examined. Furthermore, a one percentage point increase in unemployment, in most cases, decreases the chances of a currency crisis for all time samples.

	Hyp.	Sign of Significant Variable											
Time Period:		2009q3-2020q2				2000q1-2007q3				2000q1-2020q2			
Models:		1	2	3	4	5	6	7	8	9	10	11	12
Current Account/GDP	β<1	**0.951***	**0.938****	**0.938****	**0.934****	**1.065***	**1.062***	1.066	**1.129***	0.976	0.978	0.969	0.969
IMF Credit [% of Quota]	β≠1	1.001	1.002	1.002	1.002	1	1.002	1.001	1.009	1.001	1.002	1.002	1.002
Direct Investment/GDP	β<1	0.378	0.44	0.44	0.259	**0.569****	0.705	0.864	**0.322****	1.094	1.324	1.251	1.223
Portfolio Investment/GDP	β≠1	0.618	0.574	0.574	0.591	**1.836****	1.468	1.12	**3.538****	1.024	0.809	0.961	0.965
Real GDP Growth	β≠1	**1.045***	**1.057***	**1.057***	1.07	**1.166****	**1.13***	1.085	**1.227***	1.038	1.029	**1.052***	**1.053***
Real Effective Exch. Rate	β>1	**1.084***	**1.079***	**1.079***	**1.179****	1..007	1.014	1.007	0.994	0.995	1.01	1.003	0.999
Unemployment	β≠1	**0.791****	**0.773****	**0.773****	**0.724****	**0.887****	0.914	0.943	0.872	0.895	0.933	**0.854****	**0.858****
3-mo. LIBOR	β>1	0.679	1.223	1.223	1.107	1.258	1.149	1.088	1.226	**1.281***	1.264	**1.325***	**1.32***
CBOE VIX	β>1	0.987	0.956	0.956	0.963	1.018	1.002	0.958	0.82	**0.882****	**0.857****	**0.821****	**0.838****

Table 5. 1.5 Standard Deviation EMP Index regressions. * p<.10, ** p<0.05, ***p<0.01

C. 2. County Level Graphical Comparison

Having run regressions, country specific hazard functions can be drawn to ascertain relative crisis probabilities. Hazard functions are depicted for 29 countries in Graph 1. The period spans the post-recession 2009 September [quarter 3] 2020 July [quarter 2] period. On each display, the dashed line represents the average hazard function. This is drawn using the average values of each variable across all countries. Thus, the line shows the probabilities of a currency crises across time if the average values of all respective variables are used to draw the function. The second solid line on each display correspond to each country's respective hazard



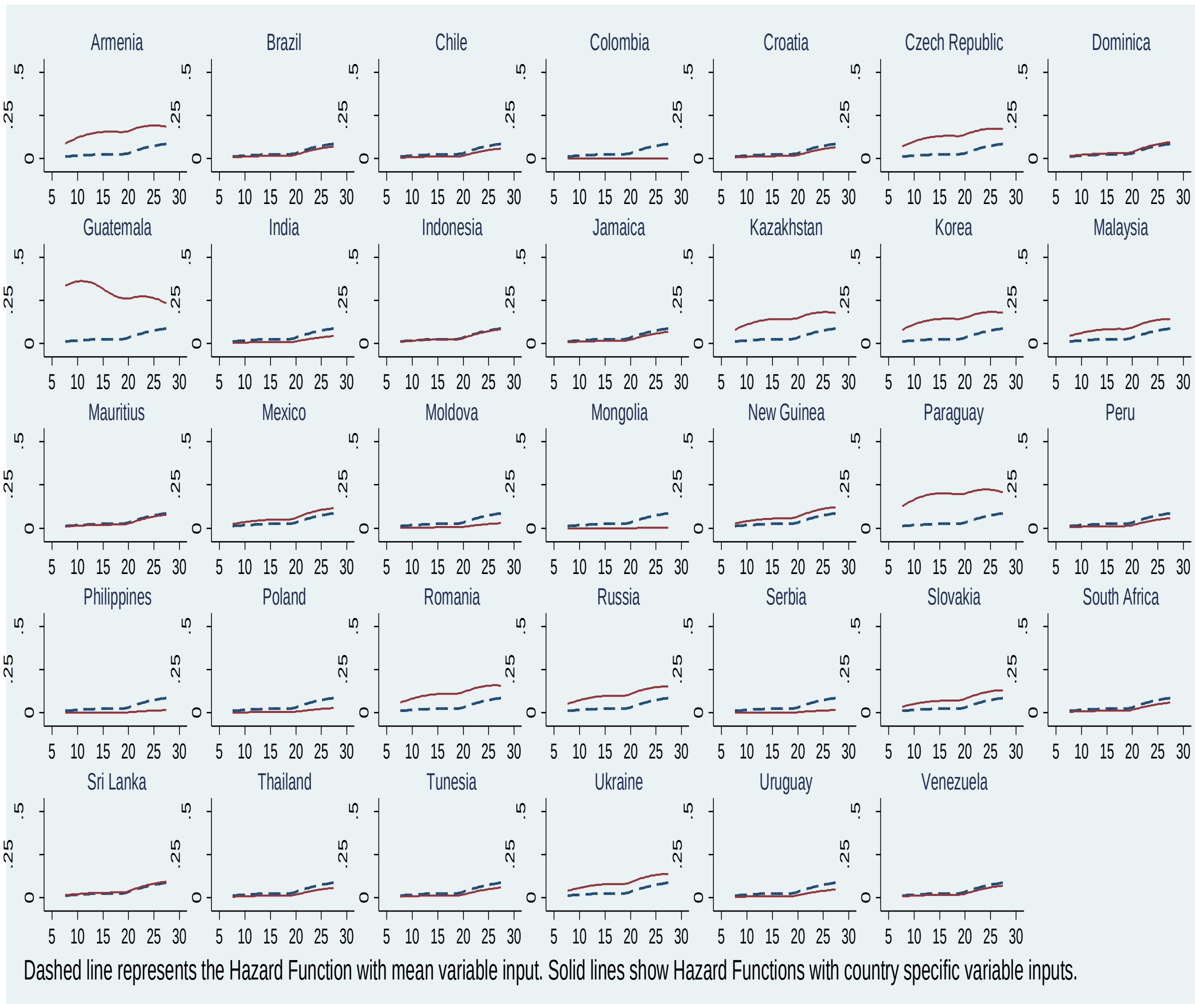
Graph 1. Country Specific Comparison to Mean Hazard Function. 2009q3 – 2020q2

function. These show hazards using a country's specific variable inputs at the beginning of each tranquil period. This essentially represents the expected probability of having a currency crisis in any future periods for each country if a country is in a tranquil period right now. The horizontal axis shows the number of quarters going forward and the vertical axis shows corresponding crisis probabilities in each quarter. If the country's hazard function, represented by the solid line, is above the average hazard function, the country can except to have a higher-than-average currency crisis probability across all time going forward. This signals an above-average risk of a currency crisis. The opposite is true for a country whose hazard curve is below the average. To exemplify, using the graphs below, Romania has an above-average risk of going through a currency crisis in the time considered and Russia is shown to have a relatively lower currency crisis risk in the same time sample. Looking at country level graphs comparisons can be drawn from the general evolution of crisis probability. If the investment window is three years (12 quarters) and a currency portfolio includes Argentine Peso and Brazilian Real, it is apparent from Graph 1 that after an investment duration of three years we can expect the Peso to have a higher chance of undergoing a currency crisis than the Real. Thus, the Peso is riskier. An investor with this two-currency portfolio may need to reduce exposure to the Peso relative to the Real or hedge the Peso more relative to the Real. In turn, the writer of the hedge would need to charge more for hedging the Peso.

On Graph 1 two countries show outlier probabilities of currency crises: Moldova and Sri Lanka. The country of Moldova is still the poorest country in Europe. In the government the Communist Party still retains political control. The pace of privatization has slowed in late 2010s and wage restrains, and debt payments arrears keep western investors cautious. Sri Lanka, after a period of civil war has started to recover in 2009. Initially, import based consumption output increased coupled with GDP growth. However, high debt levels and political crises has caused rating agencies to downgrade the country leading to a slowdown of capital inflow. As of the writing of this the risk level of the country is above average with a high corporate default risk probability (*Sri Lanka*, n.d.). Both countries suffer from a lack of built-up stability culminating in much higher currency crisis probabilities than the mean.

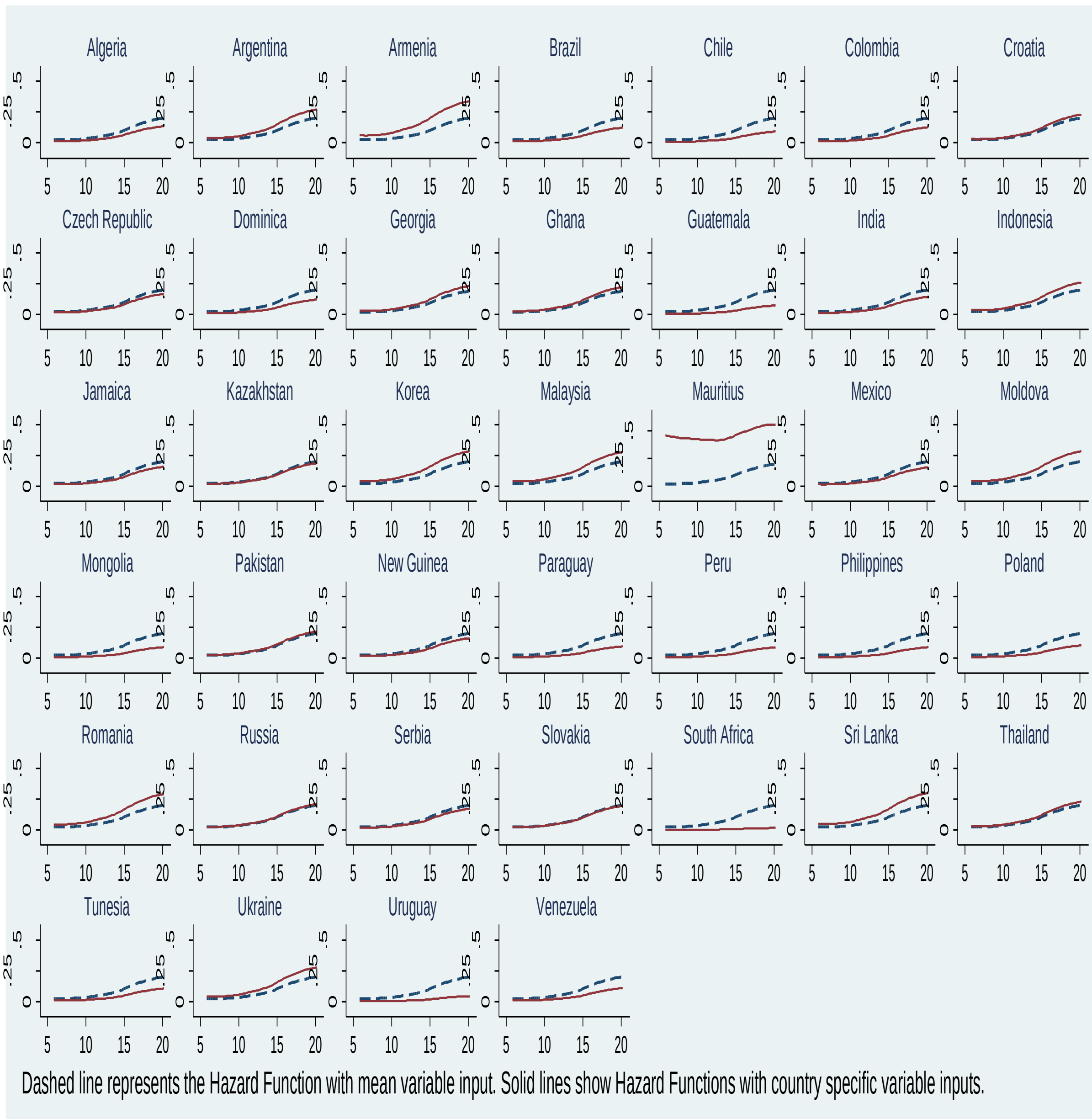
Graphing the 2000 January [quarter 1] 2007 September [quarter 3] time yields the set of country specific hazard functions that is on Graph 2. Here, 34 countries are displayed. The difference between the sample of countries between Graphs 1 and 2 is due to: a. the country has moved income categorizations, therefore is not in the lower- or upper-middle category anymore or b. the country has not experienced a larger than 1.5 standard deviation downward pressure in its currency or c. the country does not have a floating currency. Looking again at the Romanian Leu and Russian Ruble both had an above-average risk of experiencing a currency crisis in the 2000-2007 period.

To pick outlier countries on Graph 2. Guatemala and Armenia show high crisis probabilities for the whole period. Guatemala in the 2000s had one of the highest rates of illiteracy and largest rural population in the world. Coupled with an underdeveloped capital market and highly skewed wealth distribution market participants had difficulties establishing a stable currency market leading to a largely volatile currency market. Armenia after the turn of the millennium had a large international debt obligation coupled with high proportional interest payments. As unemployment remained high up to 2008 despite elevated GDP growth the country has experienced a largely skewed income distribution and anti-competitive environment. Numerous large-scale enterprises were sold off to the Russian government hindering market reforms. Both countries still had to overcome political and economic hardships to establish a stable currency market ending in higher-than-average crisis probabilities.



Graph 2. Country Specific Comparison to Mean Hazard Function. 2000q1 – 2007q3.

So far, the pre- and post-recession hazard functions were illustrated in Graphs 1 and 2. It is only logical to compare these findings to the whole period of 2000-2020. In Graph 3 the cumulative data range spanning these two decades are used to graph country specific hazards. The cumulative data set includes 39 countries. As in the above two-time ranges, Romania again is shown to have an above average currency crisis probability in Graph 3. On the other hand, in the case of Russia, the average and country specific hazard curves appear identical. This is the case as the two curves are non-distinguishable from one another. Thus, the Russian Ruble had an average riskiness in the 2000-2020 period. In Graph 3 most countries are observed to follow the average crisis probability trend. This is apparent as the country specific hazard curves are almost indistinguishable from the average.



Dashed line represents the Hazard Function with mean variable input. Solid lines show Hazard Functions with country specific variable inputs.

Graph 3. Country Specific Comparison to Mean Hazard Function. 2000q1 – 2020q2.

On Graph 3 it is evident that most currencies are average risk. Typically, an investment widow rarely lasts more than a few years. Trends tend to even out the differences between countries in hazard probabilities. Thus, the method of looking at the hazard function to gauge riskiness works best in shorter terms.

C. 3. Further Robustness Checks

Up to now the EMP index crisis threshold was defined as a 1.5 standard deviation outlier event. In the following section robustness checks are carried out changing this outlier requirement first up to two than down to one standard deviation. In each case the pre- and post-recession periods are tested as well as the overall period of 2000-2020. This follows the same format as before. The testing includes varying the exclusion-window from one to four for all three time periods. The table outputs are listed in the Appendix under regression robustness, spanning the range of Tables from 7 to 13. This section summarizes these outcomes below in Tables 5 and 6.

Table 6 shows all time samples (three) each having four different exclusion-windows. This means that two crises are considered one when they are within X quarters of one another. X is varied from one to four. The EMP threshold is set at two standard deviations. Thus, a currency crisis is registered when the EMP of a country moves two standard deviations below its mean. This requirement is more stringent requiring a more sever downward pressure on the currency for the crisis to register. Thus, the number of countries that experience this is lower. Yet, the number of observations still satisfy the minimum for a valid hypothesis test. In Table 6 magnitudes of the variables are shown. Bold values show significant variables along with their level of alpha. Two variables show robustness to some degree: real GDP growth and unemployment. Real GDP growth is the hypothesized magnitudes in all cases. The beta is larger than one indicating that a one percentage point higher real GDP growth in the past year increases the probability of a currency crisis. To reiterate these probabilities are shown by the hazard function. These probabilities are not all the same thus the curve is not a horizontal line. When real GDP growth increases this shifts the hazard probabilities for all quarters, meaning the curve shifts up in this case. Unemployment shows an even stronger robustness manifesting in ten significant betas out of the twelve regressions. All beta coefficients are less than one suggesting that a one percentage point higher unemployment lowers the probability of a currency crisis. In Table 6 other variables have shown significance but did not show up in all three time periods examined.

	Hyp.	Sign of Significant Variable											
Time Period:		2009q3-2020q2				2000q1-2007q3				2000q1-2020q2			
Models:		13	14	15	16	21	22	23	24	29	30	31	32
Current Account/GDP	β<1	0.982	0.974	0.974	0.965	**1.073***	1.066	1.061	1.061	0.966	0.961	0.951	0.953
IMF Credit [% of Quota]	β≠1	1.001	1.002	1.002	**1.003****	1	1.002	1.001	1.001	1.001	1.002	**1.002***	**1.002***
Direct Investment/GDP	β<1	0.63	0.484	0.484	**0.287***	**0.599***	0.744	0.805	0.805	1.107	1.298	1.283	1.243
Portfolio Investment/GDP	β≠1	**0.408***	0.417	0.417	**0.437***	**1.772****	1.412	1.274	1.274	1.019	0.897	1.035	1.04
Real GDP Growth	β≠1	1.006	1.033	1.033	1.071	**1.185****	**1.153****	**1.126***	**1.126***	1.024	1.028	**1.052***	**1.053***
Real Effective Exch. Rate	β>1	1.052	**1.096***	**1.096***	**1.278****	1.007	1.011	1.002	1.002	0.998	1.003	0.992	0.987
Unemployment	β≠1	**0.616****	**0.602***	**0.602***	**0.52***	**0.837****	**0.858***	**0.871***	**0.871***	0.936	0.899	**0.806****	**0.809****
3-mo. LIBOR	β>1	0.196	0.745	0.745	0.954	1.331	1.269	1.279	1.279	1.23	1.255	**1.313***	1.306
CBOE VIX	β>1	0.926	0.925	0.925	0.916	1.041	1.026	0.987	0.987	0.919	**0.883***	**0.845****	**0.868***

Table 6. 2 Standard Deviations EMP Index regressions. * p<.10, ** p<0.05, ***p<0.01

Lowering the EMP threshold requirement to one standard deviation yields somewhat different results in robustness checks. Three periods are tested again along with the four exclusion-window requirements. This is the same procedure as above, so the explanation is omitted here. Table 7 shows the results for the one standard deviation EMP requirement. Looking at all three time periods considered, again two variables show some robust significance: real GDP growth and unemployment. Real GDP growth again has the expected magnitude that is larger than one. Thus, a one percentage point increase in this variable increases the probability of a currency crisis in all quarters. Unemployment betas show a magnitude of less than one in two of the three periods considered: the post-recession of 2009-2020 and the cumulative time sample of 2000-2020. In both cases a one percentage point higher unemployment leads to a lower crisis probability. However, in the pre-recession period of 2000-2007 the betas are larger than one. Looking at Tables 5 and 6 the relationship between GDP growth rate and unemployment is negative. This manifests itself in the respective beta coefficients of the variables being larger than one and less than one. According to the results both a higher GDP growth rate and a lower unemployment level increase the probability of a crisis. This makes sense as higher levels of GDP growth generally are accommodated by lower levels of unemployment both of which lead to a higher probability of a currency crisis.

	Hyp.	Sign of Significant Variable											
Time Period:		2009q3-2020q2				2000q1-2007q3				2000q1-2020q2			
Models:		17	18	19	20	25	26	27	28	33	34	35	36
Current Account/GDP	β<1	**0.934****	**0.911****	**0.917****	**0.900****	**1.12***	1.106	1.074	1.074	1.002	1.001	1.003	1.004
IMF Credit [% of Quota]	β≠1	0.999	0.998	0.999	**0.996***	0.996	0.998	0.999	0.999	1.001	**1.002***	1.001	1.001
Direct Investment/GDP	β<1	0.658	0.638	0.684	**0.261****	0.662	0.682	0.712	0.712	1.048	1.044	1.01	0.963
Portfolio Investment/GDP	β≠1	0.743	0.742	0.679	0.747	**1.565***	1.511	1.434	1.434	0.993	0.989	1.03	1.04
Real GDP Growth	β≠1	**1.065***	**1.085****	**1.086***	1.066	**1.176***	1.131	1.103	1.103	**1.042***	**1.043***	**1.061****	**1.066***
Real Effective Exch. Rate	β>1	1.057	1.04	1.026	1.074	1.01	1.02	1.095	1.095	**1.03***	**1.03***	**1.043****	**1.045****
Unemployment	β≠1	0.87	0.872	**0.794***	0.879	1.025	1.053	**1.133***	**1.133***	0.966	0.98	0.911	**0.907***
3-mo. LIBOR	β>1	0.441	0.681	0.964	0.662	1.14	1.087	0.908	0.908	**1.419*****	**1.419*****	**1.589*****	**1.592*****
CBOE VIX	β>1	0.952	0.908	0.937	**0.844***	1.017	0.93	0.773	0.773	**0.897****	**0.908***	**0.874****	**0.859****

Table 7. 1 Standard Deviation EMP Index regressions. * p<.10, ** p<0.05, ***p<0.01

IX. Conclusions and Further Research

This study utilizes survival analysis to describe currency crisis events. In survival models a probability is assigned to an event in each period in the future. Once these probabilities are designated a curve can be drawn to show the evolution of these chances as time progresses. This curve is known as the hazard curve. It is important to point out that these probabilities are conditional, meaning that an event is assumed to occur given it has not happened yet. Furthermore, these probabilities can be influenced by variables. So, economic, financial, or other factors can be hypothesized to affect the occurrence of a currency crisis in multiple periods in the future.

Currency crises are measured by the Exchange Market Pressure Index [EMP]. This research focuses on downward pressure episodes gauged by the EMP. These crises are assigned a probability in each quarter going forward. These probabilities, using the notion of survival curves, are then graphed against a quarterly evolution of time ‘projected’ into the future. The hazard function in this study is interpreted as the chances of a currency crisis in a country given the country has not had any crisis up to that quarter. Only floating exchange rates are examined across two decades and other regimes are left for future studies.

In the first segment of this research the shape of the hazard function was tested. It is reemphasized here that the hazard curves show conditional probabilities of an event. Non-conditional probabilities of a crisis increase monotonically because it is assumed that it will occur eventually. However, conditional probabilities can decrease after a few periods. That is because conditional numbers show a proportion of countries that had the crisis out of the ones that did not have it **yet** [see example in the Appendix: Survival Analysis]. If time spent in a stable state effect the chances of a crisis happening it is shown by a non-horizontal hazard curve, as explained in the study. Theory does not give a clear answer to whether crises are a function of the time spent in normal periods, nor whether the conditional probability increases or decreases over time. A monotonically increasing function would imply that the conditional probability of a currency crisis increases constantly. This suggests that the longer a country experiences a tranquil period in its currency market the more likely a crisis will occur given it hasn't had one yet. On the other hand, an ever-decreasing function means that the highest chance of a crisis is most likely at the beginning of a tranquil period. In this case, once the currency 'survives' the vulnerable phase it is viewed as a resilient asset to investors. This study tested the hazard function being upward sloping. This can be due to an ever-increasing probability of depreciation via a possible outflow of capital. Additionally, a self-generating bubble that culminates in an investment boom can also cause an eventual reversal of inflows ever-increasing the probability of a crisis in the currency market. The emphasis is on 'ever-increasing'. This upward sloping nature suggests that as time progresses the probability of crisis is higher compared to the previous quarter, and this is true for all quarters going forward.

Looking at currency crises one can ask to what extent the evolution of these probabilities depend on changes in fundamentals. Typically, a boom or a surge set off by a policy reform or liberalization attracts inflows. At this stage, investors are attracted to new opportunities. New innovations and policies create an environment of growth. Fundamentals at this point contribute to higher investment. As more capital flows into the country "major reallocations of financial assets begin to take on a dynamic of their own involving investor herding, both rational and not, encouraged by stories that this time it is different" (Willett, Chiu, and Walter 2014, 18). The continued return on assets promotes even more inflows which strengthens investors' belief in even higher returns well beyond what is warranted by fundamentals. This deviation from fundamental pricing leads to increases in currency crisis probabilities the longer a country sustains such abnormal inflows. When investors and/or the public realize the inflated nature of risk, attitudes change, and risk aversion leads to cashing out and a currency crisis. So, the shape of the hazard function is assumed to be increasing until a crisis occurs.

The hazard curves can also show increasing chances of a currency crisis if there is a provision of easy money in the economy. Taking on excessive liability positions without warranted future cash flows can spell trouble if companies undertake such positions en masse. If expected growth perspectives do not materialize higher risk perceptions make investors cash out of the country leading to a currency crisis. The progression of ever-increasing liabilities can be an indicator of a generally increasing hazard curve similar to the case before.

In the first part of the study reference hazard functions were graphed. These show the evolution of crisis probabilities represented by the EMP index moving 1.5 standard deviations above trend. The EMP being above the trend signifies a downward pressure on the currency. The hazard curves show a generally increasing functional form. Thus, the more a country spends in a tranquil state the more likely the currency undergoes a crisis as measured by the EMP index. (A crisis and an outlier downward pressure is defined to be the same in this context.) This supports the notion that the shape of the hazard function is increasing. It is important to keep in mind that these probabilities evolve. So, the hazard curve shows probabilities not just for the next period but for a series of periods going forward. Here, the tranquil state is characterized by the absence of a sudden downward pressure on the currency. According to the hazard curves graphed in the non-parametric section of this analysis, the above-mentioned increasing trend is only interrupted by a leveling phase. So, based on the curve three periods can be distinguished. In the early phase new government policies are tested to assess resilience of the currency. If policies prove to be unsound investors may move against the currency. Following this, a period of calm is characterized by less volatility in the currency market. This may be a result of successful government policies signaling commitment to a stable financial market. In the final phase chances of a currency crisis start to increase perhaps signaling overborrowing in foreign currency, more speculation in domestic asset markets and an overvalued domestic currency. Hyman Minsky argued that an economic cycle is driven by excessive speculative activity that is defined by a bullish period followed by a market collapse. Bullish periods may begin because economic agents tend to forget the effects of previous crises. Minsky postulated that abnormally long bullish periods will cause market speculation that eventually lead to market instability and collapse. This buildup to the crisis is characterized by market speculation. The speculation is driven by borrowed funds. Once a prolonged decline in asset prices hinder investor's ability to repay debts a collapse occurs. Looking at the shape of the hazard functions, in the first phase the government is working towards a more credible exchange rate policy. However, credibility is earned over time and thus the probability of a crisis is still increasing in the first few quarters of tranquility in the country's forex market. In the second phase the market learns of prolonged and trustworthy policies that warrant a more dependable currency characterized by less downward pressure periods. This levels off the increasing of currency crisis probabilities for a while. In the third and final phase, easy money coupled with relaxed policies and speculation leads to asset price bubbles and an eventual collapse of the currency. This manifest in the increasing of crises probabilities yet once again. In general, hazard functions have shown more than a twofold increase in conditional probabilities of currency crises after the second phase. This suggests that the chances of a country going through a currency crisis more than doubles given the country has not had a crisis yet. So, if an economy experiences a period of calm for longer than the end of phase two the currency can be perceived as riskier among developing countries.

The EMP index is used to gauge when the beginning and the end of a crisis occurs. This index can look at differing severities of the pressure on the currency. It is important to point out that the EMP is not used here to measure the damage it does in the economy. A more severe downward pressure that lasts for one period may not be as damaging as a less severe one that lasts multiple periods. The persistent nature of longer crises that are less severe can create more uncertainty in the long run. In this study the EMP index is only utilized to find the beginning and an approximate end of a crisis episode and not to gauge ‘damage’ caused to the economy.

In robustness tests the severity of the crisis is altered first to two standard deviations than down to one as measured by the EMP. In both cases, the general shapes of the hazard curves show an upward sloping trend. Thus, even with different severities the same conclusion can be applied. When the more severe two standard deviation threshold is utilized the hazard functions still slope up. This means that even more severe currency crises have an increasing probability of happening as time progresses. Looking at the one standard deviation threshold measure the hazard curves still depict an increasing trend leading to the same conclusion.

Most standard measures, including the EMP, are better at detecting the start of a currency crisis than the end. To circumvent this problem a period of adjustment is allowed to occur before a new episode of ‘calm’ is determined. In robustness tests this exclusion window is varied from one to four quarters after the last quarter the EMP signaled a crisis. Thus, for each of the three time periods tested four graphs are drawn. In all cases the shapes of the hazard functions were similarly upward sloping with a slight break in the middle. This three-phase phenomenon is explained in the above paragraph for the hazard curves and can be applied here as well.

Three periods were examined and for all hazard curves were drawn. These three periods are: 2000-2007, 2009-2020 and 2000-2020. The turn of the millennium was chosen as the start because data is consistently available after this date for most of the countries. The 2000-2020 period was divided up into the above seven and eleven year two sub-periods and the separating factor was the 2007-2009 recession. In the study, for all the time periods assessed the hazard functions show an increasing trend signaling that the probability of a currency crisis increases the longer a country experiences a tranquil period. This is true for all three EMP threshold values as well for all exclusion window variants as detailed above. The particular time periods were picked

In the second proportion of this study some of the standard variables from the currency crisis literature are tested to see whether they influence the hazard curves. Here, as in all survival models, these variables are assumed to influence the hazard in equal proportion across all quarters. This manifests in a shifting of the curve up or down. Based on the literature, nine variables are included in the study. These are: the current account, direct investment, portfolio investment, IMF credit as percent of quota, real GDP growth, real effective exchange rate, unemployment, the LIBOR and the VIX. In the baseline regressions currency crises are considered when the EMP index moves 1.5 standard deviations above trend. This represents an 'average' crisis severity. Running the regressions for all time periods that includes the 2000-2007, 2009-2020 and the 2000-2020 period two variables showed significance and robustness. These were: real GDP growth and unemployment. In both cases the magnitudes of the betas were consistent with the hypothesized values. For real GDP growth a higher level of growth causes an increase in probability of a currency crisis. This could be due to the domestic asset market attracting capital inflows initially followed by a decline when there is a slowdown in asset price returns. This may cause a sell-off of assets, reversals of capital flows and possibly a currency crisis. A number of previous studies have shown the opposite effect however these were tested in a Logit model setting (Collins 1995; J. Frankel and Rose 1996, 19). Unemployment showed significance and robustness in all the time periods tested. The beta coefficient suggests that a higher level of unemployment leads to lower probabilities of a currency crisis. Unemployment is a less volatile variable that the EMP indicator. It is possible that greater unemployment is a consequence of a currency volatility rather than the other way around. Such reverse causations are unlikely to be strong except in major crises.

If investors cash-out from the domestic market due to loss in confidence or revised risk perceptions, and the sentiment is lasting, this leads to higher unemployment and lower growth in the long run. Once the elevated unemployment level is materialized, after the currency crisis, the probability of yet another crisis is less likely as the market has already repriced the currency. Thus, a higher level of unemployment signals a lower probability of a crisis. This contrasts with many findings. Eichengreen found that "countries susceptible to currency crises are those whose governments have pursued accommodating monetary policies leading to high inflation in response to deteriorating conditions in the unemployment front" (Eichengreen, Rose, and Wyplosz 1996, 16). Contrary to Eichengreen, Walti uncovered a relationship that is similar to the findings of this research. A higher level of unemployment is shown to lead to lower chances of crises and the relationship is robust. However, their observed durations are based on fixed exchange rates rather flexible regimes (Walti, n.d.). Tudela, in a survival model setting, found that high unemployment increases the vulnerability to currency crises, but the coefficient is not significant (M. M. Tudela 2002). Trying to understand the reasons for these differing results is an important topic for further research.

In the tail end of the significance the current account [CA] has shown importance consistently in two of the three time periods tested. It is important to point out that the current account represents surplus and/or deficit. A positive current account value is a surplus, and a negative value is a deficit. In this setting theory suggests that a stronger CA to GDP reduces while a higher deficit increases the probability of a crisis. This is especially the case when the country has a deficit rather that a surplus. This negative CA need to be financed through other inflows or authorities will face an eventual corrective devaluation. It is also important to mention that the level of deficit can change market sentiment. Small magnitudes do not initiate capital outflows. However, a higher amount, such as 6 percent, can undermine confidence in policy and lead to cashing out of investors en masse. In the regressions above it is assumed that the effect of CA on currency crisis probability is linear. Yet, observing the above notion, one can use binary dummies to test non-linearity for deficits. The effects may be different for surpluses and/or deficits and varying levels of deficits. This is a topic for future research. As Table 5 shows, the CA was significant in seven out of the 12 regressions run. However, the magnitude of the beta showed mixed results. This may be due to period selection. It can also be caused by differences in the magnitude of deficits that have a non-liner effect on the probability of currency crisis. Comparing this result to other studies Walti in his fixed currency regime study found similar directional correlation with the current account variable. The direction is positive implying that a higher current account to GDP ratio generally leads to lower probabilities of currency crises in a fixed regime country. This result is counter intuitive and conflicts with many of the studies from the currency crisis literature (Eichengreen et al., 1996; J. Frankel & Rose, 1996)

Further looking a Table 5 it becomes evident that the IMF quota variable is not significant. This would mean that the amount a country borrowed from the IMF has no effect on the probability of a currency going through a period of crisis. It is vital to point out that Table 5 shows significance to 10 percent. Even though, most betas on the IMF variable were close to this level they were still higher than 10 percent and thus not significant. All other variables were non-robust. Not implying the lack of importance but simply non-significance. In Tudela's research a flexible currency regime has higher chances of a crisis the higher the claims are on the government. This shows that the direction of relationship is similar but in Tudela's paper it is always significant.

To further test for robustness the threshold of the EMP index was changed to one and then to two standard deviations from the 1.5 standard deviation baseline model. In both cases, the real GDP and unemployment variables were still significant in many of the regressions. To reiterate, a lower threshold means a less severe downward pressure while a higher standard deviation requirement implies a more severe crisis of the currency. In both scenarios, a larger real GDP growth is shown to cause higher probabilities of currency crisis while elevated levels of unemployment cause lower chances of a crisis. This is consistent with the results from before and gives further backing the conclusion for robustness. Other variables have shown only occasional significance in some of the cases.

An additional contribution of this research derives from the inclusion of country specific hazard functions. These are shown in Graphs 1, 2 and 3. Aside from seeing the evolution of each countries' crisis probabilities one can compare two or more countries. Given a portfolio setting an investor can compare different time horizon investment performances for different currencies. Once a specific horizon for investment is established the currencies can be compared based on their respective probabilities of crisis. A higher probability can be interpreted as higher 'risk' necessitating more hedging or less investment. The average risk country is shown by the dashed line. The above average risk country has a hazard curve above this average. As the investment horizon may be multiple quarters an investor can use this as a guideline along with other riskiness measures to gauge the amount of investment or hedging in the respective currency.

In the country specific hazard graphs one can see that most country curves have in general an upward sloping characteristic. There are a few countries that show excessively high chances of currency crises throughout the whole observation periods. Moldova, Sri Lanka, Guatemala, Paraguay, and Mauritius all have these high levels of crisis probabilities. These can be explained by political crises, civil war, high debt levels or underdeveloped capital markets. Looking at the hazard curves we can see that the upward sloping characteristic is present for most countries in the dataset. This implies that the more any country spends in a tranquil currency period the more likely that it will experience a crisis in that market. This research did not spend much time on the explanation of why these countries have different level hazard curves. Trying to explain these differences across countries is an important topic for further research.

Given the extent of data available for the variables used in this investigation additional variations of the same study can be carried out in future research. The above research uses precision weights in the EMP index to diagnose a currency crisis. The precision weights are essentially the inverse of the variance of the respective components in the index. However, this is just one of the many possible variations that can be tested to diagnose a crisis. Possible variants for future studies can be the equal weighted index that uses the components with equal importance or weights based on the method of principal component analysis.

Looking at the hazard function it is apparent that the evolutions of currency crisis probabilities are smooth. This is partly due to the quarterly frequency used in the study. A possible test to further understand the hazard function would be to run the EMP indices based on monthly data accounting for shorter lived pressure periods. This may point out briefer crises that do not show up in quarterly frequency. These crises may be just as severe as the ones in the quarterly data so inclusion of them may uncover causalities on a shorter time scale.

The model above exclusively studies floating exchange rate regimes globally. This pools the direction and magnitude of the beta coefficient for all countries included. To further apply the notion of currency crises more broadly in the context of survival analysis, looking at fixed rate or intermediate arrangements may uncover additional variables that are significant in influencing crises in these currency regimes. Additionally, limiting the countries to certain geographical regions can establish differences in currency markets and the reasons why they undergo a crisis episode.

Most studies gauge currency crises by looking at deviations from trend. These trends are measured relative to an observation period average. This study has applied the same notion to the EMP and deviations from its mean. However, far fewer studies measure crises on a rolling window basis. The idea of the rolling window is to update the above-mentioned averages with information as it becomes available. Thus, the deviation from trend is measured relative to an average that changes as new information gets incorporated. Typically, the trend is measured based on a fixed length of time that crawls thought the observation period. The above study could be modified to measure currency crises based on the EMP through a crawling mean and standard deviation rather than the whole period's moments. The utilized EMP measure above uncovers inter-relationships between variables and the currency crisis whereas the rolling-window EMP would be used for forecasting the occurrence of a crisis as it updates the information available in the market.

In this study the EMP index is utilized to find periods when the currency is undergoing a crisis episode. In literature this is labeled a crisis. To expand on this study further survival regressions could be carried out looking at periods of depreciations exclusively. When the depreciation is severe enough it is called a currency crash. In essence, this would lead to finding variables that cause changes in the probability of large and unexpected downward movements in the price of the currency in a survival setting.

This research included domestic and international economic and financial variables. To further explore causalities, variables can be altered to account for varying economic conditions. Real GDP growth could be measured over the last few periods to account for cyclicality. Changes in trends in growth may alter investor perceptions about a country and change the probability of cashing out and a crisis. Additionally, it is well known that political and other factors can contribute to currency crises and may be used in out of sample currency crisis prediction (Leblang and Satyanath 2008). Including political and institutional variables in the above models may be useful since they have been found significant in some studies of currency crises (Chiu and Willett 2009). Thus, this dissertation suggests a rich menu for further research.

X. Appendix

A. Robustness Regressions

EMP Index Threshold: 2 stdev., TIME PERIOD: 2009q3-2020q2

	Hypotheses	Model 13	Model 14	Model 15	Model 16
Current Account/GDP	ß<1	0.982	0.974	0.974	0.965
		(0.546)	(0.428)	(0.428)	(0.441)
IMF Credit [% of Quota]	ß not=1	1.001	1.002	1.002	1.003**
		(0.250)	(0.119)	(0.119)	(0.027)
Direct Investment/GDP	ß<1	0.630	0.484	0.484	0.287*
		(0.434)	(0.250)	(0.250)	(0.099)
Portf. Investment/GDP	ß not=1	0.408*	0.417	0.417	0.437*
		(0.096)	(0.113)	(0.113)	(0.087)
Real GDP Growth	ß not=1	1.006	1.033	1.033	1.071
		(0.835)	(0.326)	(0.326)	(0.109)
REER	ß>1	1.052	1.096*	1.096*	1.278**
		(0.225)	(0.086)	(0.086)	(0.028)
Unemployment	ß not=1	0.616**	0.602*	0.602*	0.520*
		(0.049)	(0.061)	(0.061)	(0.076)
3-mo. LIBOR	ß>1	0.196	0.745	0.745	0.954
		(0.456)	(0.873)	(0.873)	(0.981)
CBOE VIX	ß>1	0.926	0.925	0.925	0.916
		(0.357)	(0.376)	(0.376)	(0.383)
Observations		27	25	25	24
AIC		75.09	60.59	60.59	45.54
BIC		86.75	71.56	71.56	56.14

Exponentiated coefficients; p-values in parentheses

2 Stdev.: Model 13: 1 quarter, Model 14: 2 quarters, Model 15: 3 quarters, Model 16: 4 quarters

* p<0.10, ** p<0.05, *** p<0.01

Table 8. EMP Index Threshold, 2 Standard Deviations, 2009q3 – 2020q2.

EMP Index Threshold: 2 stdev., TIME PERIOD: 2000q1-2007q3

	Hypotheses	Model 21	Model 22	Model 23	Model 24
Current Account/GDP	ß<1	1.073*	1.066	1.061	1.061
		(0.077)	(0.112)	(0.189)	(0.189)
IMF Credit [% of Quota]	ß not=1	1.000	1.002	1.001	1.001
		(0.996)	(0.792)	(0.852)	(0.852)
Direct Investment/GDP	ß<1	0.599*	0.744	0.805	0.805
		(0.063)	(0.377)	(0.534)	(0.534)
Portf. Investment/GDP	ß not=1	1.772**	1.412	1.274	1.274
		(0.049)	(0.334)	(0.549)	(0.549)
Real GDP Growth	ß not=1	1.185**	1.153**	1.126*	1.126*
		(0.023)	(0.040)	(0.097)	(0.097)
REER	ß>1	1.007	1.011	1.002	1.002
		(0.776)	(0.634)	(0.931)	(0.931)
Unemployment	ß not=1	0.837**	0.858*	0.871*	0.871*
		(0.024)	(0.060)	(0.097)	(0.097)
3-mo. LIBOR	ß>1	1.331	1.269	1.279	1.279
		(0.190)	(0.317)	(0.320)	(0.320)
CBOE VIX	ß>1	1.041	1.026	0.987	0.987
		(0.689)	(0.800)	(0.912)	(0.912)
Observations		25	24	23	23
AIC		68.78	65.25	60.82	60.82
BIC		79.75	75.85	71.04	71.04

Exponentiated coefficients; p-values in parentheses

2 Stdev.: Model 21: 1 quarter, Model 22: 2 quarters, Model 23: 3 quarters, Model 24: 4 quarters

* p<0.10, ** p<0.05, *** p<0.01

Table 9. EMP Index Threshold, 2 Standard Deviations, 2000q1 – 2007q3.

EMP Index Threshold: 2 stdev., TIME PERIOD: 2000q1-2020q2

	Hypotheses	Model 29	Model 30	Model 31	Model 32
Current Account/GDP	ß<1	0.966	0.961	0.951	0.953
		(0.163)	(0.151)	(0.101)	(0.114)
IMF Credit [% of Quota]	ß not=1	1.001	1.002	1.002*	1.002*
		(0.304)	(0.122)	(0.093)	(0.088)
Direct Investment/GDP	ß<1	1.107	1.298	1.283	1.243
		(0.473)	(0.141)	(0.179)	(0.248)
Portf. Investment/GDP	ß not=1	1.019	0.897	1.035	1.040
		(0.885)	(0.567)	(0.851)	(0.835)
Real GDP Growth	ß not=1	1.024	1.028	1.052*	1.053*
		(0.268)	(0.242)	(0.070)	(0.066)
REER	ß>1	0.998	1.003	0.992	0.987
		(0.926)	(0.891)	(0.726)	(0.582)
Unemployment	ß not=1	0.936	0.899	0.806**	0.809**
		(0.298)	(0.142)	(0.014)	(0.019)
3-mo. LIBOR	ß>1	1.230	1.255	1.313*	1.306
		(0.146)	(0.146)	(0.097)	(0.111)
CBOE VIX	ß>1	0.919	0.883*	0.845**	0.868*
		(0.179)	(0.090)	(0.037)	(0.090)
Observations		39	36	35	34
AIC		149.7	123.2	109.3	103.3
BIC		164.7	137.4	123.3	117.0

Exponentiated coefficients; p-values in parentheses

2 Stdev.: Model 29: 1 quarter, Model 30: 2 quarters, Model 31: 3 quarters, Model 32: 4 quarters

* p<0.10, ** p<0.05, *** p<0.01

Table 10. EMP Index Threshold, 2 Standard Deviations, 2000q1 – 2020q2.

EMP Index Threshold: 1 stdev., TIME PERIOD: 2009q3-2020q2

	Hypotheses	Model 17	Model 18	Model 19	Model 20
Current Account/GDP	ß<1	0.934**	0.911**	0.917**	0.900**
		(0.036)	(0.016)	(0.028)	(0.036)
IMF Credit [% of Quota]	ß not=1	0.999	0.998	0.999	0.996*
		(0.390)	(0.282)	(0.358)	(0.061)
Direct Investment/GDP	ß<1	0.658	0.638	0.684	0.261**
		(0.344)	(0.372)	(0.463)	(0.046)
Portf. Investment/GDP	ß not=1	0.743	0.742	0.679	0.747
		(0.184)	(0.219)	(0.146)	(0.272)
Real GDP Growth	ß not=1	1.065*	1.085**	1.086*	1.066
		(0.078)	(0.041)	(0.053)	(0.168)
REER	ß>1	1.057	1.040	1.026	1.074
		(0.179)	(0.331)	(0.534)	(0.175)
Unemployment	ß not=1	0.870	0.872	0.794	0.879
		(0.158)	(0.172)	(0.106)	(0.359)
3-mo. LIBOR	ß>1	0.441	0.681	0.964	0.662
		(0.460)	(0.711)	(0.970)	(0.781)
CBOE VIX	ß>1	0.952	0.908	0.937	0.844*
		(0.486)	(0.216)	(0.409)	(0.091)
Observations		30	28	27	25
AIC		95.88	81.22	76.06	59.65
BIC		108.5	93.21	87.72	70.62

Exponentiated coefficients; p-values in parentheses

1 Stdev.: Model 17: 1 quarter, Model 18: 2 quarters, Model 19: 3 quarters, Model 20: 4 quarters

* p<0.10, ** p<0.05, *** p<0.01

Table 11. EMP Index Threshold, 1 Standard Deviation, 2009q3 – 2020q2.

EMP Index Threshold: 1 stdev., TIME PERIOD: 2000q1-2007q3

	Hypotheses	Model 25	Model 26	Model 27	Model 28
Current Account/GDP	ß<1	1.120*	1.106	1.074	1.074
		(0.080)	(0.177)	(0.387)	(0.387)
IMF Credit [% of Quota]	ß not=1	0.996	0.998	0.999	0.999
		(0.567)	(0.852)	(0.947)	(0.947)
Direct Investment/GDP	ß<1	0.662	0.682	0.712	0.712
		(0.189)	(0.276)	(0.377)	(0.377)
Portf. Investment/GDP	ß not=1	1.565*	1.511	1.434	1.434
		(0.081)	(0.174)	(0.291)	(0.291)
Real GDP Growth	ß not=1	1.176*	1.131	1.103	1.103
		(0.080)	(0.236)	(0.335)	(0.335)
REER	ß>1	1.010	1.020	1.095	1.095
		(0.752)	(0.681)	(0.235)	(0.235)
Unemployment	ß not=1	1.025	1.053	1.133*	1.133*
		(0.652)	(0.412)	(0.093)	(0.093)
3-mo. LIBOR	ß>1	1.140	1.087	0.908	0.908
		(0.567)	(0.768)	(0.777)	(0.777)
CBOE VIX	ß>1	1.017	0.930	0.773	0.773
		(0.872)	(0.592)	(0.129)	(0.129)
Observations		27	25	24	24
AIC		76.26	64.82	55.80	55.80
BIC		87.93	75.79	66.40	66.40

Exponentiated coefficients; p-values in parentheses

1 Stdev.: Model 25: 1 quarter, Model 26: 2 quarters, Model 27: 3 quarters, Model 28: 4 quarters

* p<0.10, ** p<0.05, *** p<0.01

Table 12. EMP Index Threshold, 1 Standard Deviation, 2000q1 – 2007q3.

EMP Index Threshold: 1 stdev., TIME PERIOD: 2000q1-2020q2

	Hypotheses	Model 33	Model 34	Model 35	Model 36
Current Account/GDP	ß<1	1.002	1.001	1.003	1.004
		(0.938)	(0.970)	(0.916)	(0.872)
IMF Credit [% of Quota]	ß not=1	1.001	1.002*	1.001	1.001
		(0.157)	(0.084)	(0.167)	(0.438)
Direct Investment/GDP	ß<1	1.048	1.044	1.010	0.963
		(0.764)	(0.790)	(0.957)	(0.852)
Portf. Investment/GDP	ß not=1	0.993	0.989	1.030	1.040
		(0.933)	(0.906)	(0.771)	(0.704)
Real GDP Growth	ß not=1	1.042*	1.043*	1.061**	1.066**
		(0.062)	(0.069)	(0.042)	(0.037)
REER	ß>1	1.030*	1.030*	1.043**	1.045**
		(0.060)	(0.072)	(0.027)	(0.024)
Unemployment	ß not=1	0.966	0.980	0.911	0.907*
		(0.432)	(0.666)	(0.112)	(0.097)
3-mo. LIBOR	ß>1	1.419***	1.419***	1.589***	1.592***
		(0.005)	(0.008)	(0.002)	(0.003)
CBOE VIX	ß>1	0.897**	0.908*	0.874**	0.859**
		(0.018)	(0.055)	(0.019)	(0.011)
Observations		47	44	40	39
AIC		192.9	169.7	135.7	129.4
BIC		209.5	185.8	150.9	144.4

Exponentiated coefficients; p-values in parentheses

1 Stdev.: Model 33: 1 quarter, Model 34: 2 quarters, Model 35: 3 quarters, Model 36: 4 quarters

* p<0.10, ** p<0.05, *** p<0.01

Table 13. EMP Index Threshold, 1 Standard Deviation, 2000q1 – 2020q2.

A. List of Variables Included in the Study

Stock variables represent **averages over the last 3 months** unless otherwise noted. These are: exchange rate, reserves, base money, domestic IMF credit, Real Effective Exchange Rate, unemployment and the VIX. Flow variables are interest rate, GDP, current account, direct and portfolio investment, real GDP growth (growth in flow) and LIBOR.

To clarify, level variables are differentiated from change variables. The level variables are exchange rate, reserves, money base, domestic IMF credit, unemployment, interest rate, GDP, current account, direct and portfolio investment, REER, LIBOR and VIX. The change variable is real GDP growth.

Exchange Rate: National Currency per U.S. Dollar, Period Average, **Average of Last Quarter**.

Base Money: Otherwise called M2. Monetary and Financial Accounts, Broad Money, **Average of Last Quarter, Domestic Currency**. The sum of currency, checkable deposits and savings accounts.

Reserves: Total Reserves excluding Gold, **Average of Last Quarter, US Dollar**. **In Millions.**

'Reserves used in the EMP': Reserves/Base Money in **U.S. Dollar.**

Interest rate: Money Market Rate, **Percent per Annum**.

GDP: National Accounts, Expenditure, Gross Domestic Product, Nominal, **Annual**, **in USD**. **In Millions**

Current Account: Balance of Payments, Current Account, Goods and Services, Net [BPM6], Net Inflow(+)/ Net outflow(-), **Annual**, **US Dollar. In Millions**
Current Account/GDP = 100*Current Account/GDP. **A unit increase indicates that current account relative to GDP is now one percentage point higher.**

Domestic IMF Credit: Fund Accounts, Use of Fund Credit and Loans as Percent of Quota, **Average of Last Quarter, Percent. A unit higher IMF credit shows a percentage point higher credit from the IMF relative to the country's quota.**

Foreign Direct Investment = Financial Account, Net Lending (+) / Net Borrowing (-) (Balance from Financial Account), Direct Investment, Net Acquisition of Financial Assets, **Annual, US Dollars. In Millions**
Direct Investment/GDP = 100*Direct Investment/GDP. **A unit increase implies that direct investment relative to GDP is now one percentage point higher.**

Portfolio Investment = Financial Account, Portfolio Investment, Net Acquisition of Financial Assets, Debt Securities, **Annual, US Dollars. In Millions**
Portfolio Investment/GDP = 100*Portfolio Investment /GDP. **A unit increase shows that portfolio investment is one percentage point higher relative to GDP.**

Real GDP Growth: National Accounts, Expenditure, Gross Domestic Product, Real, **Percent Change in GDP from Previous Quarter. A unit increase signifies a one percentage point higher GDP growth relative to previous year.**

REER: REER measured relative to a base year, Index. **A one-unit higher value implies a one-UNIT higher REER compared to the previous year.**

Unemployment: Labor Markets, Unemployment Rate, Quarterly Release, **Annualized Percent**. **A unit increase represents a one percentage point higher unemployment.**

3-mo. LIBOR: 3-Month (LIBOR), U.S. Dollar, Percent, Quarterly, **Average of the last quarter**. **A unit higher LIBOR shows a one percentage point higher international interest rate.**

CBOE VIX: CBOE VIX, Quarterly, **Average of last quarter. A one-unit higher VIX signifies a one absolute UNIT increase in this index.**

B. List of Countries Included in the Study

The list is composed of countries from the Lower Middle-Income and Upper Middle-Income categories of the World Bank's World Development Indicators. It is based on GNI per capita in USD using the Atlas Method. Overall, there are 37 countries in the study pool. Development of countries at the beginning of the crisis is considered.

Argentina	Mongolia
Armenia	Pakistan
Brazil	Papua New Guinea
Chile	Paraguay
Colombia	Peru
Croatia	Philippines
Czech Republic	Poland
Dominican Republic	Romania
Georgia	Russia
Ghana	Serbia
Guatemala	Slovak Republic
India	South Africa
Indonesia	Sri Lanka
Jamaica	Thailand
Kazakhstan	Tunisia
Korea	Ukraine
Malaysia	Uruguay
Mauritius	Venezuela
Mexico	

C. Survival Analysis

C. 1. The Survival Function Definition:

$$P(A \cap B) = P(A \mid B)P(B) \text{ and}$$

$$P(A_1 \cap A_2 \cap ..A_k)=P(A_1)P(A_2|A_1)P(A_3|A_2 \cap A_1).. \qquad \text{(for multiple events)}$$

The survival function assumes: $a_t < T \leq a_{t+1}$,where T is time when failure occurs.

Let us define a failure/event as a phenomenon at the end of a duration or spell that indicates the termination of a particular state (normal economic times, change in exchange rate regime or in our case a speculative attack on the currency after a tranquil period).

By definition the true survival function is: $S(t) = P(T \geq a_{t+1})$, the probability of surviving to **at least** a_{t+1}

Survival**s** to time t happen at the same time thus it is a joint probability:

$$= P(T \geq a_{t+1}, T \geq a_t \ldots T \geq a_2, T \geq _1)$$

$$=P(T \geq a_{t+1}|T \geq a_t)P(T \geq a_t|T \geq a_{t-1}) \ldots P(T \geq a_2|T \geq a_1)P(T \geq a_1)$$

$$S(t) = \prod_{t=1}^{k} P(T \geq a_{t+1}|T \geq a_t)P(T \geq a_1)$$

Let's define the hazard function: $h(t) = \lim_{\Delta t \to 0} \frac{P(t \leq T < t+\Delta t | T \geq t)}{\Delta t}$ eq.(1)

For a discrete time, failure occurs at $a_1 \ldots a_t$. Additionally, h(t) can also be expressed as $h(t)= P(T=a_t|T \geq a_t)$ at the t^{th} failure time. This implies that the hazard function represents an instantaneous probability of failure in the next instant given survival to **at least** a_t. Essentially, the hazard is a measure of risk. The greater the hazard between t_1 and t_2 the greater the risk of failure in this time interval

(Altman, 2009) . It is vital to point out that the survival function can take on probabilities between zero and one, but the hazard function ranges between zero and infinity.

The probability of not failing is: 1 – P(T=a_t | T≥a_t). As a result, the joint probability of not failing up to T is the product of the individual survival probabilities up to the t^{th} failure time.

$$S(t) = \prod_{t=1}^{k}[1-P(T=a_t \mid T \geq a_t)$$

The survival up to the t^{th} failure time is the discrete C.D.F. of the instantaneous survival probabilities.

$$h(t) = P(T=a_t|T \geq a_t)$$

$$S(t) = \prod_{t=1}^{k} P(T \geq a_{t+1}|T \geq a_t)P(T \geq a_1)$$

$$S(t) = \prod_{t=1}^{k} P(1-h(t))$$

Let: d_t = number of countries who failed at a_t. Important: a_t is the time when T (event/failure/end of an exchange rate regime/stability) occurs. Not all time t include a failure.

r_t = number of countries in the risk set that have not yet had an exchange rate "episode (regime failure, etc). From one failure time to the next, r_i decreases by the number of countries who 'fail' plus the number of countries that are censored.

h(t): the point probability of failure in the t^{th} time period.

So, h(t) = $\frac{dt}{rt}$ because this gives the instantaneous probability of failure given survival to that point.

$$\text{So, } 1-h(t) = 1 - \frac{dt}{rt}$$

As a result, the survival function is:

$$S(t) = \prod_{t=1}^{k}(1 - \frac{dt}{rt}) = \prod_{t=1}^{k}(1 - h(t)) \qquad \text{eq.(2)}$$

At the beginning of the t^{th} period the risk set is composed of countries that have not 'failed' up to t – 1 minus those countries that have failed or were censored between $t-1 \leq T < t$. Thus, eq.(2) **can be used for both censored and uncensored (failed) duration data**. For a more complete description see: Cleves (Cleves et al., 2008).

C. 2. The Semi-Parametric COX Proportional Hazard Model:

In this study the COX Proportional Hazard method (Cox, 1972) is utilized to calculate coefficients of co-variants x for survival curves. In the Cox model the hazard function is:

$$h(t|x) = h_0(t) \exp(\beta_1 x_1 + \beta_2 x_2 + \ldots \beta_k x_k) = h(t|x_1, x_2, \ldots x_k) \qquad \text{eq.(3)}$$

The model provides an estimate for the Beta coefficients, but the baseline hazard function [$h_0(t)$ is not directly calculated. Essentially the baseline function gives the hazard when all the co-variants are zero.

The COX PH model incorporates the covariate into the survival function. Each country j has a set of covariates x_j and a parameter of multiplication. The assumption here is that each 'entity' has a hazard function that is proportional to the baseline hazard function. [$h_0(t)$]. Thus, any two countries have a hazard function whose ration is constant over time: $h_j(t) = h_0(t|p_j)$

In the COX model $p_j = \exp(\beta x)$ where β is a vector regression coefficients and x is a vector of covariates. The model is called semi-parametric because the baseline hazard is not given. It is deducted from the data. This is essentially the same as estimating the Kaplan-Meyer survival function from the data.

COX regression: Event times: $t_1 < t_2 < \ldots\ t_i$,$i \in [1,k]$

Risk set: those who have not failed up to event i.

So, the probability of an individual j having an event is [at t_i]

$$P(\text{event for j} \mid t_i) = \frac{hj(ti)}{hj(ti)+hj2(ti)+\cdots hjn(ti)}$$

people who are still at the risk set: $R \in [j, j_2, \ldots j_n]$

The proportional hazard says:

$$P(j \mid t_i) = \frac{pjh0(ti)}{ho(ti)pj+ho(ti)pj2+\cdots+ho(ti)pjn} = \frac{ho(ti)pj}{\sum_{j \in Ri} h0(ti)pj}$$

The probability of an event occurring for j does not depend on time anymore.

Using the COX Proportional Hazard assumption: $p_j = \exp(\beta x)$

$$P(j \mid t_i) = \frac{\exp(\beta x)}{\sum_{j \in Rj} \exp(\beta xj)}$$

β depends on the order in which events occur, not when these events/failures happen. That is why the time element is not important. The joint probability of all the event happening in the order specified by the data at any given point in time (the joint density function) is the product of individual joint densities at all event times up to failure time t_i.

$$L[\beta] = \prod_{i:Ci=1} \frac{\exp(\beta' xi)}{\sum_{j:Tj \geq Ti} \exp(\beta' xi)}$$

Since we do not know the times of failure only the order at which they occur it is called the partial likelihood.

To find the β parameters a maximum likelihood estimation is carried out.

$$\max_{\beta 1, \dots\ \beta d} L(\beta_1, \dots\ \beta_d) = \max_{\beta 1, \dots\ \beta d} \prod_{ti} \frac{\exp(\beta x j)}{\sum_{j \in Ri} exp(\beta x j)}$$

$$= \sup_{\beta} \prod_{ti} \frac{\exp(\beta x j)}{\sum_{j \in Ri} \exp(\beta x j)}$$

C. 3. The Partial Likelihood Function:

Let x_i be a vector of variables and T_i be the observed time (failure or censoring event occuring) and C_i be the censoring. [$C_i = 1$: failure event, $C_i = 0$: censoring] at time i. Here, 'failure' refers to an event/failure occurring for a country at time T. Censoring signals that a country has not had a failure/event by the end of the time period under study.

The likelihood function (Breslow) is:

$$L[\beta] = \prod_{i:Ci=1} \frac{\exp(\beta' xi)}{\sum_{j:Tj \geq Ti} \exp(\beta' xi)}$$

and the log likelihood function is:

$$\ln(L[\beta]) = \sum_{i=Ci=1} \beta' x_i - \ln[\sum_{j:Tj \geq Ti} \exp(\beta' xj) \qquad \text{eq.(4)}$$

which is maximized to the beta coefficients via the Score Function:

$$\frac{\delta ln(L[\beta])}{\delta \beta} = \sum_{i:Ci=1} [\ x_i - \frac{\sum_{j:Tj \geq Ti} \exp(\beta' xj * xj)}{\sum_{j:Tj \geq Ti} \exp(\beta' xj)}\ ]$$

Failures or events may occur on the same date. Several approaches can be utilized to deal with tied failure events. The above method uses the notion of Breslow. This essentially implies that in this method all events are distinct and all subjects that failed contribute to the risk set fully.

A second method the study uses in robustness tests is the Efron method. In this case each of the countries that fail at time t has a partial contribution to the risk set. The likelihood function and the partial likelihood functions are slightly different from Berlow.

Let T_j be failure time and z_j the indicator such that $C_i = 1$ [event/failure] and it includes all outstanding hazard functions: Y_i at that failure/event. Also, let p_j be the total number of tied failures/events at time T_i. (Efron method)

$$L[\beta] = \prod_{i:Ci=1}\left(\frac{\prod_{i\in zj}\exp(\beta\prime xi)}{\prod_{n=0}^{pj-1}\left(\sum_{i:Yi\geq Ti}\exp(\beta' xi) - \sum_{i\in zj}\left(\frac{n}{pj}\exp(\beta' xi)\right)\right)}\right)$$

$$\mathrm{Ln}(L[\beta]) = \sum_{i:Ci=1}\left(\sum_{i\in zj}\beta' xi - \sum_{n=0}^{pj-1} ln\left(\sum_{i:Yi\geq Ti}\exp(\beta' xi) - \frac{n}{pj}\sum_{i\in zj}\exp(\beta' xi)\right)\right)$$

The Efron method is best for everyday use (Gillen, 2016) . In the above study the Efron methods is applied to the dataset.

The variance**s** are found from the diagonal entries of the Hessian:

$Var[\beta] = -[H]^{-1}$,where $H = -[d^2L[\beta]$ is an n by n (n = number of covariates) matrix.

C. 4. Interpretation of the Survival Output:

First, let's look at the relationship between the hazard function (pdf, cdf), survival function and probability density function (pdf, cdf). Let T denote the survival time and let $f_T(t)$ be the probability density function. The cumulative distribution function of T is:

$$F_T(t) = P(T \le t) = \int_0^t f_T(t)dt$$

The $F_T(t)$ is the probability of failure **by** time t.

After some simple transformations the hazard function is also defined as (proof omitted):

$$h_T(t) = \frac{f(t)}{S(t)} \ [= \lim_{\Delta t \to 0} \frac{P(t \le T < t + \Delta t | T \ge t)}{\Delta t}, \text{ from eq.(1)}] \qquad \text{eq.(5)}$$

The interpretation is similar to eq.(1) except it is expressed as a ratio of the density function and survival curve.

By definition the CDF of the hazard function is:

$$H(t) = \int_0^t h(t)dt$$

$$= \int_0^t \frac{f(t)}{S(t)} dt$$

$$= \int_0^t -\frac{d}{dt}\log(S(t))dt, \quad \text{as } S(t) = 1 - F(t) \text{ and } \frac{d}{dt}F(t) = f(t)$$

$$= -\log S(t)$$

Thus: $S(t) = \exp(-H(t))$ eq.(6)

The CDF of the hazard function with covariates is:

$$H[t|x] = \int_0^t h(t|x)dt = \int_0^t h_0(t)\exp(\beta' x)dt = \exp(\beta' x) \int_0^t h_0(t)dt = H_0(t)\exp(\beta' x) \quad \text{eq.(7)}$$

$S_0(t)$, $H_0(t)$ and $h_0(t)$ signifies the baseline survival, cumulative and non-cumulative hazard functions when all the covariates are assumed to be zero. [See eq.(3)]

So the survival function is: from eq.(6)

$$S[t|x] = \exp[-H(t|x)]$$

$$= \exp[-\exp(\beta' x)H_0(t)]$$

$$= \exp[-H_0(t)]^{\exp(\beta' x)}$$ if $S[t|x] = \exp[-H(t|x)]$ then $S_0[t] = \exp[-H_0(t)]$

$$S[t|x] = [S_0(t)]^{\wedge}\exp[\beta' x] \quad \text{eq.(8)}$$

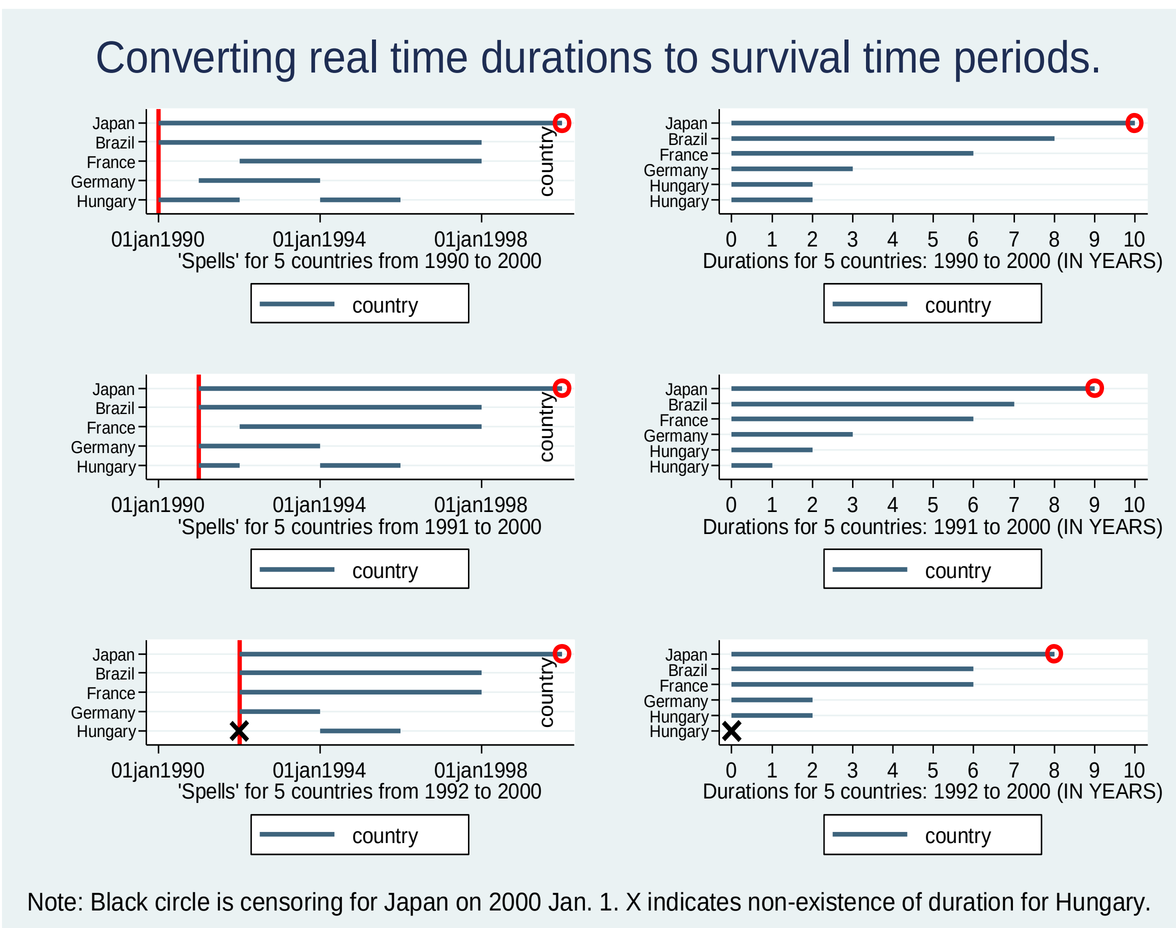
As it specifies survival probability (the baseline survival function): $S_0(t) \in [0,1]$.

When the output in STATA is run using the nohr command the table provides the vector of β coefficients as seen in eq.(8). As evident for eq.(8) the uncharacteristic nature of survival analysis is that causality for **β coefficients** is inverse **on survival** time. That implies that **when β for a covariate is positive the probability of survival to time t goes down (and thus the probability of failure goes up) as the covariate increases**, given $S_0(t)] \in [0,1]$.

C. 5. Duration, the Kaplan-Meyer Curve and the Survival Curve Graphs:

Duration: In the following section an explanation of the survival data construction is detailed. The data is assumed to run from 1990s to exactly 2000, yearly. In each case, the left graph shows the spell of a country or the duration of a particular state. When the blue line ends it signifies a failure for that country. In the first graph the data goes from 1990 to 2000 and each country is in a state represented by the blue line. Let us use a currency example. Japan is in a tranquil period throughout the whole observation period, so it is right censored, and duration is 10 years. Brazil does not have a speculative attack until 1998 so duration is 8 years. Hungary had two speculative attacks one in 1992 and one in 1996 so it has two durations.

When the observation window starts in 1991, on Graph 4. some durations are shortened by one year because they started before 1991 and the others stay the same as these began after 1991. The graphs on the bottom represent an observation window from 1992 to 2000. In this case, Japan's, Brazil's and Germany's exchange rate spells are affected as they started before 1992.

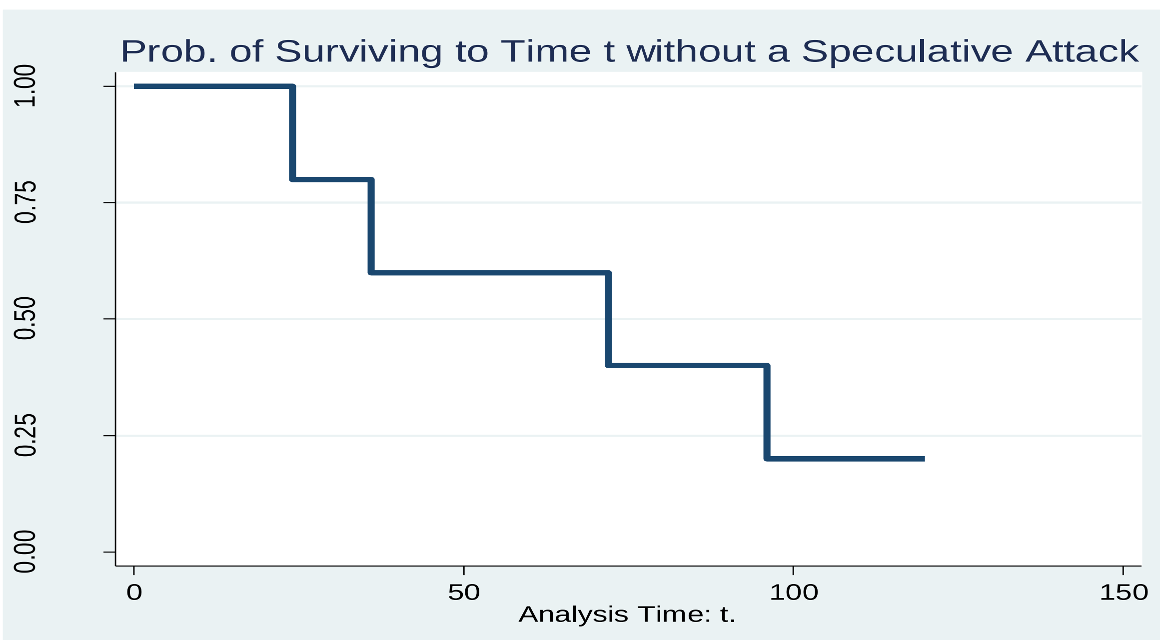


Graph 4. Real Time Durations and Survival Time Periods

One of Hungary's spells drops out at it ends by 1992. All others are unaffected. From here we can see the construction of survival data and how it effects duration.

Kaplan-Meyer Curve: Let's assume that the study examines speculative attacks and survival represents duration up to time t when the attack takes place. This is represented in Graph 5. The differing countries survived to year 2, 3, 5, 8 and 10 respectively (the data represents months on the graph). This curve essentially indicates the corresponding survival probabilities relative to each year. This does not consider economic variables on survival probabilities.

Thus, the probability of any country to survive to year 5 [60 months] is 60 percent. We can also say that the average country has a 60 percent chance of survival without a speculative attack to year 3 and up to year 5 from today.



Graph 5. Kaplan-Meyer Curve

C. 6. The relationship of Survival and Failure Graphs:

This paper presents the findings of significant variables in the context of failure graphs. Thus, it is important to explain here the relationship between the failure graphs and survival graphs. The two are essentially just the complements of one another and so the relationship can be expressed as:

$S(t) = 1 – F(t)$

where S(t) is the survival and F(t) is the failure functions. Given this relationship, the failure function is a monotonically increasing function of time. All other interpretations of time dependence and covariate effect is defined similarly but in a complementary fashion to survival graphs.

C. 7. The COX Proportional Hazard [PH] Model:

Let's look at the model output and the corresponding survival curve. If we assume that we have five countries and their survival time is 2, 3, 5, 8, and 10 years respectively than we would get the K-M curve without considering variables. However, the PH model does consider variables. Let's assume these five countries have reserve levels at the beginning of their tranquil period (the absence of a speculative attack) of 10, 24 18, 23 and 31 (billions). After running the COX maximum likelihood functions, we get the output shown in Table 14. As we can see the coefficient of the reserve variable is negative. However, the causality is inverse. [For further explanation, see this Appendix: Interpretation of the Survival Output (Beta Coefficients).] This can be observed on Graph 6.

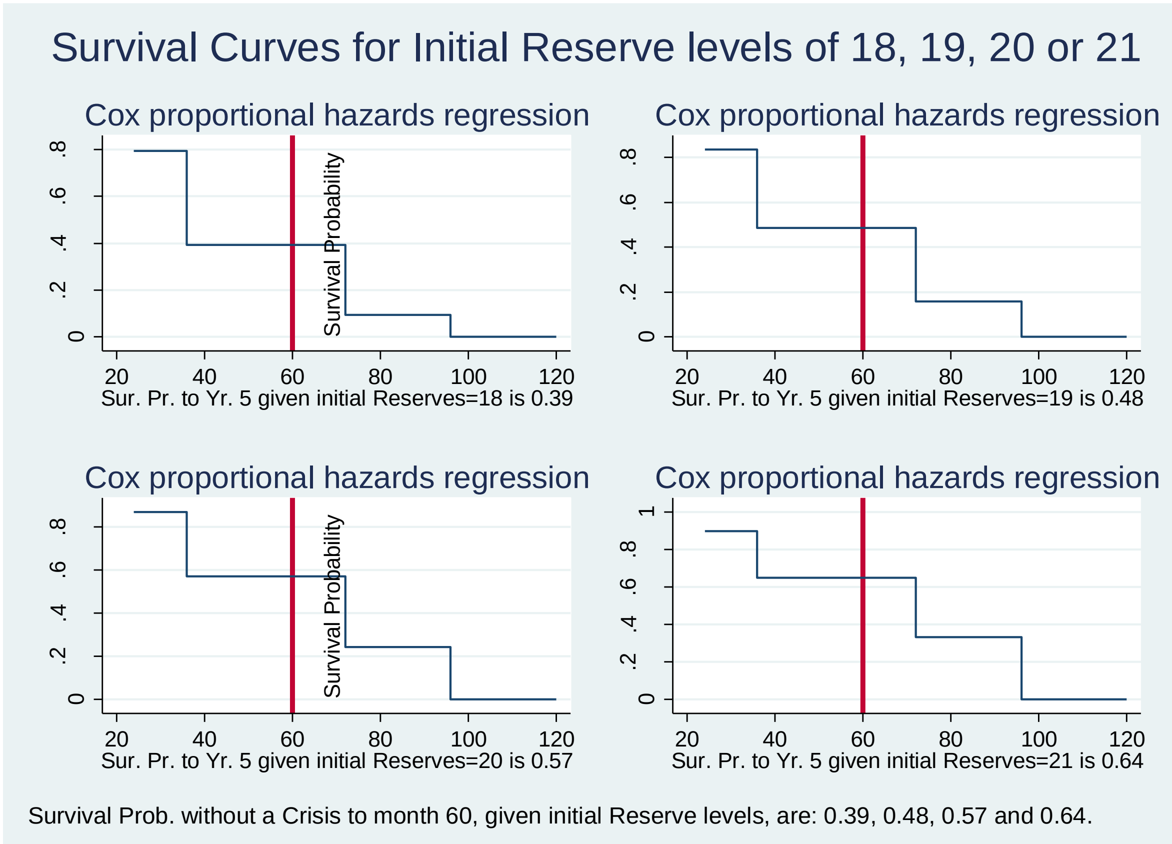
```
Cox regression -- no ties

No. of subjects =            5                  Number of obs   =         5
No. of failures =            4
Time at risk    =          348
                                                LR chi2(1)      =      4.50
Log likelihood  =   -2.5350366                  Prob > chi2     =    0.0338
```

_t	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
reserves	-.2570938	.1603491	-1.60	0.109	-.5713722	.0571846

Table 14. The COX Proportional Hazard Output

In this study the data is set up so when the country is in a tranquil period (the absence of a speculative attack on the currency) the observer can evaluate the probability of a currency attack in one, two, x years from today. When the covariates are considered, they are imputed as today's values. So, for this example, the level of reserves of a country **today** has a certain effect on the country's survival in a tranquil period. After running the survival regression, we can look at the survival curve for differing levels of reserves that prevails at the beginning of the tranquil period. As Graph 6 shows for an initial reserve level of 18 (billion) the probability of a speculative attack **not** occurring by year five is 39 percent. However, when this initial reserve level is 21 the probability increases to 64 percent.



Graph 6. Survival Curves and Variable Effect

The advantage of time duration analysis is that multiple variables can be considered simultaneously in the study and multiple probabilities can be extracted for a series of future time periods.

C. 8. The relationship between the failure function and hazard function.

In the following section an example is provided to show the construction of the hazard function relative to the failure function. The graphs are based on the tables provided for clarification.

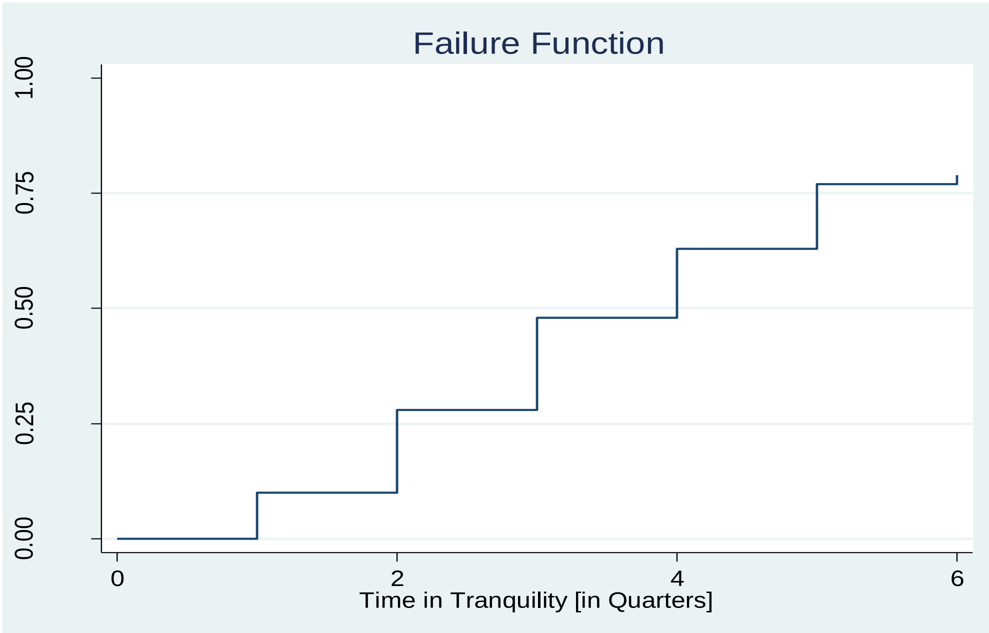
C.8.1. Failure Probability

The probability of a country experiencing a currency crisis is represented by the failure probability. Table 15 below exemplifies a hypothetical scenario. It shows the number of countries that survived **to** the end of a particular quarter without a currency crisis as well as the number of countries that failed **up to** the end of that quarter. The two are complements. Furthermore, the table shows the probability of a currency crisis for a country **by** the end of a particular quarter.

	Number of countries who **survived** to **the END of quarter X**.	Number of countries who had the currency crisis **BY the END of quarter X** (**start with 100 countries**)	Probability of an currency crisis **by end of quarter X.** [Cumulative Density Function]
Quarter 0	100	0	0/**100**= 0
Quarter 1	90	10	10/**100**= 0.1
Quarter 2	72	28	28/**100** = 0.28
Quarter 3	52	48	48/**100** = 0.48
Quarter 4	37	63	63/**100** = 0.63
Quarter 5	23	77	77/**100** = 0.77
Quarter 6	21	79	79/**100** = 0.79

Table 15. Failure Probability Example

Graph 7 below represents the probability of a currency crisis by the end of a particular quarter. The probabilities correspond with the last column of Table 15. According to the graph below the more time a country spends in a tranquil state the more likely it is to 'fail' because eventually every country fails; nothing lasts forever.



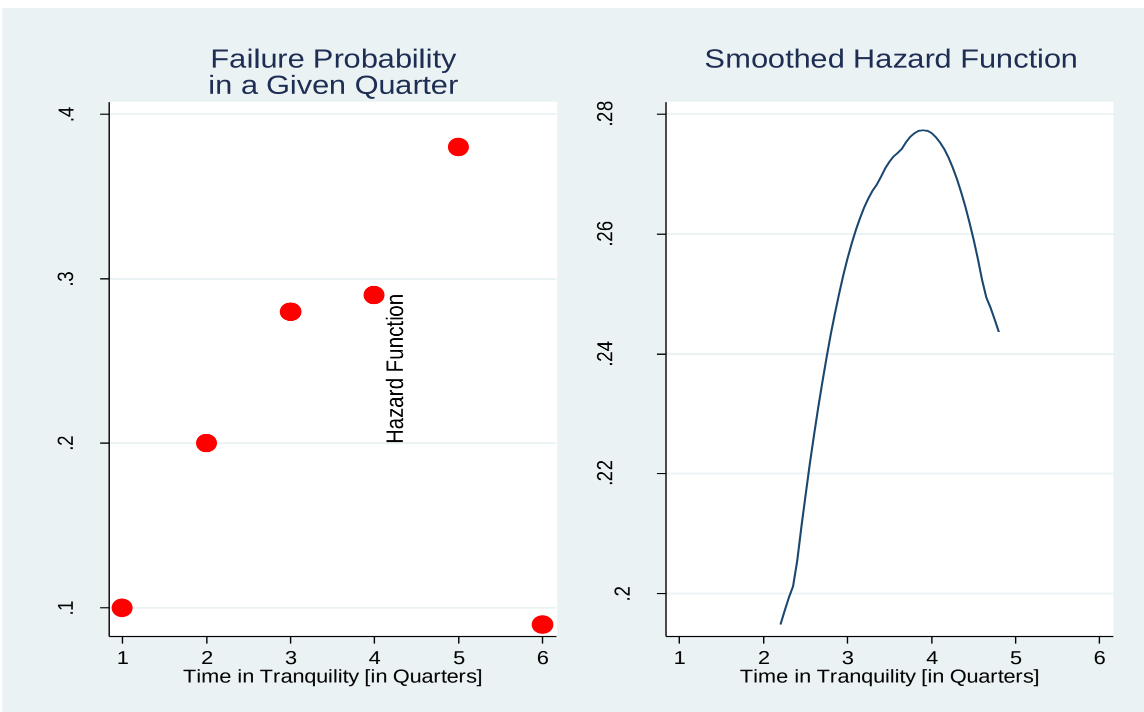
Graph 7. Failure Function Example

C.8.2. Failure probability in each quarter:

Table 16 below looks at the number of countries that had a currency crisis in each quarter. The first two numerical columns are the same as Table 15 and the third column shows the number of countries that experienced a crisis **in** that quarter. The probability of a crisis in each quarter is shown in the last column. It is calculated as the ratio of countries who had a currency crisis in each quarter AND the number of countries who survived to the end of **last** quarter. Here, **the end of a quarter and beginning of the next quarter is assumed to be the same**.

	Number of countries who survived to the END of quarter X.	Number of countries who had the currency crisis BY the END of quarter X (start with 100 countries)	Number of countries who had the CURRENCY CRISIS in quarter X.	Probability of an currency crisis IN quarter X
Quarter 0	100	0		
Quarter 1	90	10	10	10/100 = 0.10
Quarter 2	72	28	18	18/90 = 0.2
Quarter 3	52	48	20	20/72 = 0.28
Quarter 4	37	63	15	15/52 = 0.29
Quarter 5	23	77	14	14/37 = 0.38
Quarter 6	21	79	2	2/23 = 0.09

Table 16. Conditional Failure Probability Example



Graph 8. Hazard Function Example

Graph 8 above shows the plotted points from the last column of Table 16. The right-hand side graph shows a fitted Kernel curve to the plotted data points. The smoothing technique is beyond the scope of this explanation, however as it is apparent the curve closely follows the trend of the data points. This smoothed curve is called the Hazard Function in survival analysis. The plotted points in this context can be called hazard probabilities corresponding to the values on the y-axis.

C. 9. Beta Coefficient Interpretation

The nine variables included in the study affect the hazard probabilities in each quarter. Each variable in this study is assumed to shift the hazard function in equal proportion across all quarters. The hazard function is the curve that describes the probability of a currency crisis in each quarter and is graphed in the above Graph 5. When a variable changes, this is assumed to shift the probability of a currency crisis in each quarter. This variable affects this probability in equal proportion **regardless** of what quarter we are looking at (the proportional hazard assumption in time duration analysis). **When the Beta coefficient in the table output in the dissertation is larger than one the hazard probability increases** (the hazard graph) **when the coefficient increases; and vice versa**. For example, if the Beta is 1.2 and the variable increases by a unit of one the hazard probability of a currency crisis increases by 20 percent. (a magnitude of 1.2). If the beta is 0.9 then a unit increase in the variable will cause a 10 percent reduction in the hazard probability of a currency crisis. Looking at decreases in the variable, if the Beta is 1.2 and the variate goes down by one unit the probability of a currency crisis decreases by 20 percent. If the Beta is 0.9 then a unit decrease causes a 10 percent increase in the hazard probability of the crisis.

In sum:

Beta>1 and variable increases by one unit the hazard probability of crisis goes up.

Beta<1 and variable increases by one unit the hazard probability of crisis goes down.

Beta>1 and variable decreases by one unit the hazard probability of crisis goes down.

Beta<1 and variable decreases by one unit the hazard probability of crisis goes up.

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