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DURATION ANALYSIS OF INTEREST RATE SPELLS: CROSS-NATIONAL STUDY OF INTEREST RATE POLICY

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Abstract

A duration analysis is adopted in this study to investigate the determinants of the "interest rate spells" across ten countries (or area). Both parametric and nonparametric methods are employed for the analysis. It is found that the length of "interest rate spells" is affected by both the rate of inflation and the rate of economic growth. In contrast, the influence of exchange and unemployment rates proved to be insignificant and the lagged interest rate is significant only for Denmark. The empirical results support the contention that central banks usually design their interest rate policies based on the Taylor Rule.

Key Words: duration analysis; Taylor rule; interest rate spells; parametric models; nonparametric models

JEL classifications: C14; C41; C52; E43; E52

I. *Introduction*

During the past decades, central banks have attached increasing importance to low and stable inflation. In practice, a short-term interest rate can be used as the policy instrument to keep price stable, i.e., central banks set the operating target for the interest rate, and make changes to it in response to the variations in inflation rate and output gap[1], which is referred to

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[1] Output gap is the gap between the actual and projected values of the GDP.

as the Taylor rule (Taylor 1993). Past experiences have shown that central banks could achieve low and stable inflation without sacrificing other objectives. In addition, stable price always brings stable economic growth[2]. Not surprisingly, the practice of the Taylor rule has attracted growing interest among policy makers in recent years, with the aim to keep price stable through adjusting the interest rate.

However, most of the current research studies in print tend to approach the Taylor rule using linear regression (see, for example, Taylor 1999; Clarida, Gali, and Gertler 1998). Only Shih and Giles (2009) applied duration analysis, which is superior to linear regression in that it is applicable to censored data, and can take into consideration time-varying covariates as well. The authors defined a period during which an operating target for the interest rate remains unchanged as an “interest rate spell,”and came to a conclusion consistent with the Taylor rule, i.e. the length of an interest rate spell is directly related to the annual inflation rate and the monthly growth rate of the gross domestic product (GDP). For their analysis the most recent interest rate spell was ongoing at the end of the study period, leading to right-censored data. While an interest rate spell may last for several months, the inflation rate, growth rate of GDP, exchange rate, and unemployment rate are available on a monthly basis, hence the time-varying nature of the covariates. Due to the characteristics of the data, duration analysis is an appropriate method for the study of the Taylor rule in designing the interest rate policy.

Shih and Giles (2009) directed their analysis to the experiences of Canada which adopts the inflation-targeting policy. As one type of interest rate policies, inflation-targeting is achieved with the announcement of numerical target ranges of the inflation rate over a specified time horizon. In order to test whether their result holds for other countries, we extend their study through a cross-national analysis of ten countries (or area), in which eight countries adopt the inflation-targeting policy and the other two do not. Theoretically, optimal policy should be history dependent rather than purely forward looking[3] (Woodford 2003); hence, in addition to the simple Taylor rule, we also augment the Taylor rules by replacing current inflation rate and GDP growth rate by lags of these variables, namely lag-based Taylor rule (Tchaidze 2004). The lag-based Taylor rule indicates the history dependence of the interest rate policy; that is, any adjustment of the operating target of the interest rate depends on the past economic conditions. It is observed in our study that the length of interest rate spells is affected by both the inflation rate and GDP growth rate, and both the original and the lag-based Taylor rules explain the data well. However, the exchange and unemployment rates are insignificant factors, a conclusion consistent with that of Shih and Giles (2009). Hence, this study helps establish a verifiable link between the interest rate policy and the Taylor rule, which may provide governments with useful guidance in deciding monetary policies.

The remaining four sections of the paper are as follows: Section II reviews the relevant literature on the research of the Taylor rule. Section III introduces the econometric framework. Section IV presents the empirical findings, and in Section V we state our conclusions.

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[2] See Woodford (2003) or Bernanke et al. (1999) for a detailed discussion.

[3] Forward looking policy takes into account the expectations of future economic conditions.

II. *Literature Review*

Taylor (1993) suggested that central banks adjust their short-term interest rates in response to deviations between the actual inflation rate and the target rate, as well as the output gap. This is referred to as the Taylor rule and it is modeled as $i_t = \beta_0 + \beta_1(\pi_t - \pi^*) + \beta_2 y_t$, where i_t is the short-term nominal interest rate at time t, π_t is the actual inflation rate, π^* is the target rate of inflation, y_t is the output gap, and β_0,β_1, and β_2 are the corresponding coefficients. This rule provides guidance for implementing interest rate policies in many countries, especially those that adopt the inflation targeting policy.

Based on the simple Taylor rule, researchers augmented Taylor rule to make it more widely applicable. Taylor (1999) extended the rule into $i_t = \beta_0 + \beta_1(\pi_t - \pi^*) + \beta_2 y_t + \beta_3 e_t + \beta_4 e_{t-1}$, where e_t is the exchange rate at time t. Clarida, Gali, and Gertler (1998) examined the interest-rate smoothing behavior for six countries by adding the lag of the interest rate. Gerlach and Schnabel (2000) estimated the Taylor-rule for the European Monetary Union by adding quarterly dummy variables to describe the exchange market turmoil from March 1992 to March 1993. Tchaidze (2004) replaced the current inflation rate and output gap with lags of these variables, because it is impossible to obtain the current inflation and output at the time when changes are made to the interest rate. Aklan and Nargelecekenler (2008) applied the generalized method of moments (GMM)[4] to estimate the backward-looking and forward-looking Taylor rules for Turkey when the period of inflation targeting was taken into consideration. Cukierman and Muscateli (2008) proposed a nonlinear Taylor-rule for a smooth-transition model which allows the marginal effects of inflation deviation and output gap on short-term interest rates to change smoothly. Ftiti (2008) studied both the dynamic and static Taylor-rule models for New Zealand to test whether the interest rate smoothing was adopted by the central bank.

However, most of the econometric techniques applied to the study on Taylor rule have been limited to linear regressions. To the best knowledge of us, only Shih and Giles (2009) applied the method of duration analysis and arrived at a conclusion consistent with the Taylor rule. As an extension to their study, we examine the determinants of interest rate spells through a cross-national study, in an attempt to discover a more discernable relationship between the Taylor rule and a country's interest rate policy.

III. *Methodology*

Duration analysis is a statistical technique used for modeling the time to an event. Three equivalent functions are commonly used to describe the distribution of duration data: survivor function, hazard function, and cumulative hazard function. Suppose the duration time is a continuous random variable T, then the survivor function at time t is $S(t) = \Pr(T \geq t)$, i.e., the probability that T is at least as great as some positive value t. The hazard function, $h(t)$, is defined as the probability of the instantaneous completion of an event at time t, given that it

[4] Please refer to Hall (2005) for an excellent survey of the GMM technique in econometrics and Zhou, et al. (2008) for a recent study on the properties of GMM.

TABLE 1. SURVIVOR, HAZARD, AND PROBABILITY DENSITY FUNCTIONS FOR THE PARAMETRIC METHOD

	Exponential	Weibull	Log-logistic
Survivor function, $S(t)$	$\exp(-\lambda t)$	$\exp(-(\lambda t)^p)$	$1/(1+(\lambda t)^p)$
Hazard function, $h(t)$	λ	$\lambda p(\lambda t)^{p-1}$	$\lambda p(\lambda t)^{p-1}/(1+(\lambda t)^p)$
Probability density function, $f(t)$	$\lambda \exp(-\lambda t)$	$\lambda p(\lambda t)^{p-1} \exp(-(\lambda t)^p)$	$\lambda p(\lambda t)^{p-1}/[(1+(\lambda t)^p)]^2$

has lasted that long, i.e., $h(t)=\lim_{\Delta t\to 0}\frac{\Pr\{t\leq T<t+\Delta t\,|\,T\geq t\}}{\Delta t}=\frac{f(t)}{S(t)}$, where $f(t)$ is the probability density function of T at time t and $f(t)=\lim_{\Delta t\to 0}\frac{\Pr(t\leq T<t+\Delta t)}{\Delta t}$. The cumulative hazard function is defined as $\Lambda(t)=\int_0^t h(u)du$, i.e., the integral of the hazard over time. In this study, both parametric and nonparametric methods are adopted to examine the determinants of the length of an interest rate spell.

1. Parametric Models

Since the functional form of the hazard function is unknown, we follow Shih and Giles (2009) in applying three parametric models—exponential, Weibull, and log-logistic—and select the most appropriate distribution based on the scores of the Akaike information criterion (AIC), if the covariates in competing models are all significant. The survivor, hazard, and probability density functions for the three models are summarized in Table 1, in which two parameters λ and p are involved. We define the scale parameter $\lambda\equiv\exp(-\beta' X_i)$, where X_i is a vector of the covariates for the i th observation, and β is the corresponding vector of coefficients, $i=1, ..., n$. The parameter p determines the shape of the hazard function of various distributions. The exponential model has a constant hazard function with $p=1$. In the Weibull model, the hazard function is increasing with time when $p>1$, decreasing when $p<1$, and reduces to the exponential model if $p=1$. The hazard function of the log-logistic model has an inverted U-shape when $p>1$, and decreases with time if $p<1$.

The unknown parameters λ and p can be estimated through the maximum likelihood method and the log-likelihood function takes the form

$$\log L=\sum_{i=1}^{n}\{\delta_i \log[S_i(t_i)]+(1-\delta_i) \log[f_i(t_i)]\}, \tag{1}$$

where $\delta_i=0$ for complete observations, and $\delta_i=1$ for right-censored observations. $f_i(t_i)$ is the probability density function for observation i that completes at time t_i; and $S_i(t_i)$ is the survivor function of observation i at time t_i, $i=1, ..., n$. To deal with the time-varying covariates, we follow Kalbfleisch and Prentice (2002) to divide the interval between 0 and t_i into k_i subintervals. The covariates remain fixed within each of the k_i intervals, but may change from one interval to the next. The log-likelihood function (1) can then be expressed as

$$\log L=\sum_{i=1}^{n}\{(1-\delta_i) \log[h_i(t_i)]-\sum_{j=1}^{k_i}\int_{t_{j-1}}^{t_j}h(u)du\}, \tag{2}$$

where $h_i(t_i)$ is the hazard function for the i th interest rate spell at time t_i.

2. Nonparametric Model

In addition to parametric models, non-parametric approaches are also applicable to duration analysis such that the assumption about the distribution of the duration time can be relaxed. The Kaplan-Meier estimator (Kaplan and Meier 1958), also called the product limit estimator, is a widely-used non-parametric method in duration analysis. It is based on a rank ordering of survival or censoring times. Suppose there are n observations, among which r are completed and $n-r$ are right-censored. For the r completed cases, their duration times are rank-ordered as $t_{(1)}<t_{(2)}<\cdots<t_{(r)}$. Let n_i be the number of observations at time $t_{(i)}$, and d_i be the actual number of completions at $t_{(i)}$. Thus, the conditional survival probability at time $t_{(i)}$ is $\frac{n_i-d_i}{n_i}$, and the Kaplan-Meier estimator of the survivor function at time t is $\hat{S}(t)=\prod_{t_{(i)}\leq t}\frac{n_i-d_i}{n_i}$.

IV. *Data and Empirical Results*

1. Data

In this section, we undertake a comparative analysis investigating the key monetary policies in ten countries (or area), in which eight countries adopt the inflation-targeting policy, i.e., Australia, Euro Area, New Zealand, Norway, Poland, South Korea, Switzerland, and the United Kingdom, and the other two do not, i.e., Denmark and the United States. These countries (or area) are selected because: (1) they all use the interest rate as the monetary policy instrument to keep the price stable, and (2) they are all OECD countries, which means that we can have access to the OECD online database to collect their economic data. Ten series are collected for each country, with the definitions and the corresponding notations listed as follows.

T	Length of interest rate spells
Inflation_t	Annual inflation rate at time t, i.e. % change in consumer price index (CPI) over the same month of last year
Inflation_{t-1}	Inflation at one period lag
Interest_{t-1}	Short-term interest rate at one period lag, monthly average
GDPGR_t	Monthly growth rate of the chained volume GDP, seasonally adjusted
GDPGR_{t-1}	GDPGR at one period lag
Exchange_t	Exchange rate at time t, i.e. national currency per US dollar, monthly average
Exchange_{t-1}	Exchange rate at one period lag
Unemploy_t	Seasonally adjusted unemployment rate at time t
Unemploy_{t-1}	Unemployment rate at one period lag

The data for the inflation targeting countries range from their adoption date of this policy to December 2008[5], and the data for the other two countries are from January 1999 to December

TABLE 2. ADOPTION DATES OF INFLATION TARGETING FOR THE EIGHT INFLATION-TARGETING COUNTRIES

Country	Adoption Date
Australia	April 1993
Euro Area	January 1999
New Zealand	March 1990
Norway	March 2001
Poland	October 1998
South Korea	April 1998
Switzerland	January 2000
The United Kingdom	October 1992

2008. The adoption date of each inflation-targeting country is listed in Table 2. The length of interest rate spells is obtained from the central bank website of each country, and the other data series come from the OECD statistics online database[6]. All data are collected on a monthly basis, except GDP; thus a quadratic-match average was employed to convert the quarterly GDP to monthly frequency through the EViews package.

2. Empirical Results

Figure 1 depicts the Kaplan-Meier survivor functions for the ten countries (or area). The survivor functions are downward sloping and decline at a decreasing rate. In general, the survival rate declines sharply within approximately four months, and the chance that an interest rate spell lasts for more than one year is lower than 20%. The Kaplan-Meier method ignores the impact of covariates; hence the hazard functions appear different from those of the parametric methods presented below.

In the parametric analysis, we first estimate the simple Taylor-rule models under three distributions — exponential, Weibull, and log-logistic — and select the most appropriate distribution based on the significance of covariates and AIC scores. Then, under the preferred distribution, we compare the performances of seven models which involve the simple Taylor rule model and six augmented Taylor rule models, as summarized in Table 3. The LIMDEP econometrics package is used for the estimation of the parametric models.

Table 4 summarizes the estimated results of the simple Taylor-rule models. It shows that the Taylor-rule is applicable for all of the ten countries (or area); however, there is no unique preferred distribution of the interest rate spell. The best model specification for the Euro Area and Denmark is exponential; while the log-logistic model is the most suitable for the others.

Under the preferred distribution for each country, the performances of seven models are compared to investigate the determinants of the length of the interest rate spell. The results are reported in Table 5, in which only models with all covariates being statistically significant are presented. It is observed that Models 1 (simple Taylor rule) and 5 (lag-based Taylor rule) explain the data well for all the countries. According to the AIC scores, the simple Taylor rule

[5] New Zealand has practiced inflation targeting since 1990, but the website of Reserve Bank of New Zealand only provides the data on interest rates from 1999.

[6] This website is http:// www.sourceoecd.org/database/OECDStat.

TABLE 3. SEVEN MODELS STUDIED UNDER THE PREFERRED DISTRIBUTION

Model	Covariates in the model
1	Inflation_t, GDPGR_t
2	Inflation_t, GDPGR_t, Interest_{t-1}
3	Inflation_t, GDPGR_t, Exchange_{t-1}
4	Inflation_t, GDPGR_t, Unemploy_{t-1}
5	Inflation_{t-1}, GDPGR_{t-1}
6	Inflation_{t-1}, GDPGR_{t-1}, Exchange_{t-1}
7	Inflation_{t-1}, GDPGR_{t-1}, Unemploy_{t-1}

TABLE 4. TAYLOR-RULE MODEL FOR THE TEN COUNTRIES (OR AREA)

Country		Exponential	Weibull	Loglogistic	Country		Exponential	Weibull	Loglogistic
Australia	Inflation_t	0.347^{***}	0.317^{***}	**0.145****	Euro Area	Inflation_t	**0.736*****	0.734^{***}	0.466^{***}
		[0.000]	[0.000]	**[0.029]**			**[0.000]**	[0.000]	[0.000]
	GDPGR_t	0.630^{***}	0.585^{***}	**0.580*****		GDPGR_t	**0.515****	0.514^{**}	0.315^{*}
		[0.001]	[0.016]	**[0.009]**			**[0.012]**	[0.013]	[0.080]
	p	1.000	0.814	**1.591**		p	**1.000**	0.991	1.792
	AIC	0.977	0.969	**0.910**		AIC	**0.957**	0.970	0.946
New Zealand	Inflation_t	0.299^{***}	0.311^{***}	**0.182*****	Norway	Inflation_t	3.245^{***}	2.488^{***}	**2.130*****
		[0.000]	[0.000]	**[0.001]**			[0.000]	[0.000]	**[0.000]**
	GDPGR_t	0.541^{***}	0.565^{***}	**0.295****		GDPGR_t	-0.214^{***}	-0.372^{**}	**−0.314****
		[0.001]	[0.000]	**[0.018]**			[0.000]	[0.040]	**[0.045]**
	p	1.000	1.114	**2.264**		p	1.000	0.469	**1.024**
	AIC	1.082	1.089	**1.009**		AIC	4.496	3.560	**3.434**
Poland	Inflation_t	0.108^{**}	0.121^{***}	**0.102*****	South Korea	Inflation_t	0.309^{***}	0.327^{***}	**0.203*****
		[0.027]	[0.001]	**[0.001]**			[0.000]	[0.000]	**[0.000]**
	GDPGR_t	0.646^{***}	0.705^{***}	**0.358*****		GDPGR_{t-1}	0.504^{***}	0.495^{***}	**0.473*****
		[0.001]	[0.000]	**[0.008]**			[0.002]	[0.000]	**[0.002]**
	p	1.000	1.411	**2.609**		p	1.000	1.162	**1.908**
	AIC	1.108	1.065	**1.011**		AIC	0.938	0.947	**0.935**
Switzerland	Inflation_t	0.980^{***}	0.963^{***}	**0.660*****	UK	Inflation_t	0.351^{***}	0.365^{***}	**0.243*****
		[0.000]	[0.000]	**[0.001]**			[0.000]	[0.000]	**[0.000]**
	GDPGR_t	1.037^{***}	1.035^{***}	**0.781****		GDPGR_{t-1}	0.634^{***}	0.661^{***}	**0.423*****
		[0.001]	[0.002]	**[0.032]**			[0.000]	[0.000]	**[0.005]**
	p	1.000	0.955	**1.686**		p	1.000	1.139	**2.129**
	AIC	0.967	0.981	**0.957**		AIC	1.022	1.023	**0.967**
U.S.	Inflation_t	0.203^{***}	0.195^{***}	**0.082****	Denmark	Inflation_t	**2.405*****	1.906^{***}	1.646^{***}
		[0.000]	[0.003]	**[0.050]**			**[0.000]**	[0.000]	[0.000]
	GDPGR_t	0.491^{**}	0.488^{**}	**0.297****		GDPGR_t	**0.342*****	0.375	0.233
		[0.011]	[0.018]	**[0.050]**			**[0.001]**	[0.165]	[0.266]
	p	1.000	0.953	**2.631**		p	**1.000**	0.508	2.407
	AIC	1.172	1.182	**0.980**		AIC	**3.039**	2.531	1.202

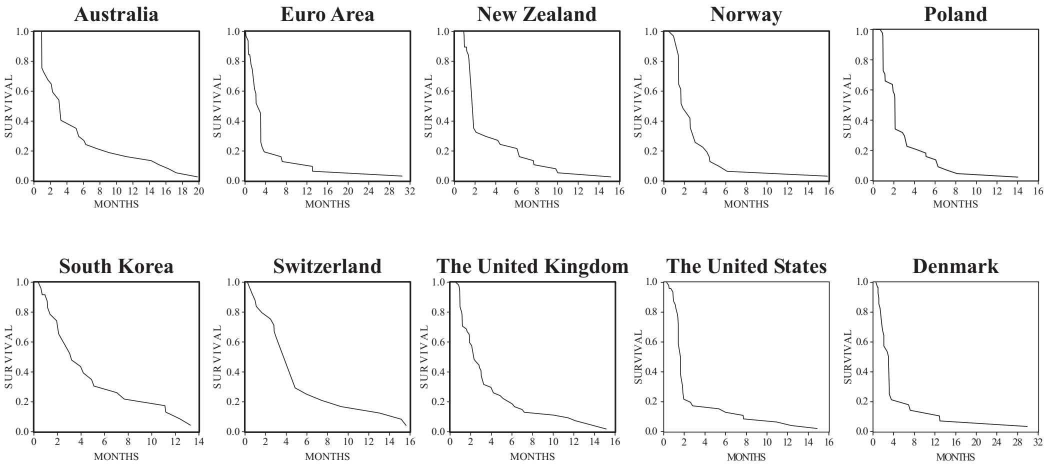
Note: 1. Significant levels: *** 1%; ** 5%; and * 10%.
2. P-values appear in the square brackets.
3. The preferred model for each country is marked in bold.
4. p refers to the shape parameter (see section III.1).

Table 5. Models with Statistically Significant Covariates under the Preferred Distribution

Country (Preferred distribution)		Model 1	Model 5	Model 2
Australia (Log-logistic)	Inflation_t	**0.145****		
		[0.029]		
	GDPGR_t	**0.580*****		
		[0.009]		
	Inflation_{t-1}		0.158**	
			[0.025]	
	GDPGR_{t-1}		0.459**	
			[0.034]	
	p	**1.591**	1.567	
	AIC	**0.910**	0.919	
New Zealand (Log-logistic)	Inflation_t	0.182***		
		[0.001]		
	GDPGR_t	0.295**		
		[0.018]		
	Inflation_{t-1}		**0.180*****	
			[0.001]	
	GDPGR_{t-1}		**0.342*****	
			[0.006]	
	p	2.264	**2.267**	
	AIC	1.009	**1.007**	
Poland (Log-logistic)	Inflation_t	0.102***		
		[0.001]		
	GDPGR_t	0.358***		
		[0.008]		
	Inflation_{t-1}		**0.112*****	
			[0.001]	
	GDPGR_{t-1}		**0.323****	
			[0.019]	
	p	2.609	**2.660**	
	AIC	1.011	**1.007**	
Switzerland (Log-logistic)	Inflation_t	**0.660*****		
		[0.001]		
	GDPGR_t	**0.781****		
		[0.032]		
	Inflation_{t-1}		0.404**	
			[0.012]	
	GDPGR_{t-1}		1.151***	
			[0.002]	
	p	**1.686**	1.596	
	AIC	**0.957**	0.974	
US (Log-logistic)	Inflation_t	0.082**		
		[0.050]		
	GDPGR_t	0.297**		
		[0.050]		
	Inflation_{t-1}		**0.076****	
			[0.049]	
	GDPGR_{t-1}		**0.376****	
			[0.015]	
	p	2.631	**2.714**	
	AIC	0.980	**0.964**	
Euro Area (Exponential)	Inflation_t	0.736***		
		[0.000]		
	GDPGR_t	0.515**		
		[0.012]		
	Inflation_{t-1}		**0.714*****	
			[0.000]	
	GDPGR_{t-1}		**0.726*****	
			[0.004]	
	p	1.000	**1.00**	
	AIC	0.957	**0.927**	
Norway (Log- logistic)	Inflation_t	2.130***		
		[0.000]		
	GDPGR_t	−0.314**		
		[0.045]		
	Inflation_{t-1}		**2.246*****	
			[0.000]	
	GDPGR_{t-1}		**−0.448****	
			[0.044]	
	p	1.024	**1.088**	
	AIC	3.434	**3.418**	
South Korea (Log-logistic)	Inflation_t	**0.203*****		
		[0.000]		
	GDPGR_t	**0.474*****		
		[0.003]		
	Inflation_{t-1}		0.229***	
			[0.000]	
	GDPGR_{t-1}		0.283***	
			[0.003]	
	p	**1.908**	1.763	
	AIC	**0.935**	0.974	
UK (Log-logistic)	Inflation_t	**0.243*****		
		[0.0000]		
	GDPGR_t	**0.423*****		
		[0.0051]		
	Inflation_{t-1}		0.232***	
			[0.000]	
	GDPGR_{t-1}		0.453***	
			[0.003]	
	p	**2.129**	2.109	
	AIC	**0.967**	0.969	
Denmark (Exponential)		Model 1	Model 5	Model 2
	Inflation_t	2.405***		**0.958*****
		[0.000]		**[0.000]**
	GDPGR_t	0.342***		**0.350*****
		[0.001]		**[0.002]**
	Interest_{t-1}			**0.860*****
				[0.000]
	Inflation_{t-1}		2.385***	
			[0.000]	
	GDPGR_{t-1}		0.293***	
			[0.005]	
	p	1.000	1.000	**1.000**
	AIC	3.039	3.142	**2.893**

Note: 1. Significant levels: *** 1%; ** 5%; and * 10%.
2. P-values appear in the square brackets.
3. The preferred model for each country is marked in bold.
4. p refers to the shape parameter (see section III.1).

FIG. 1. Kaplan-Meier Survivor Functions



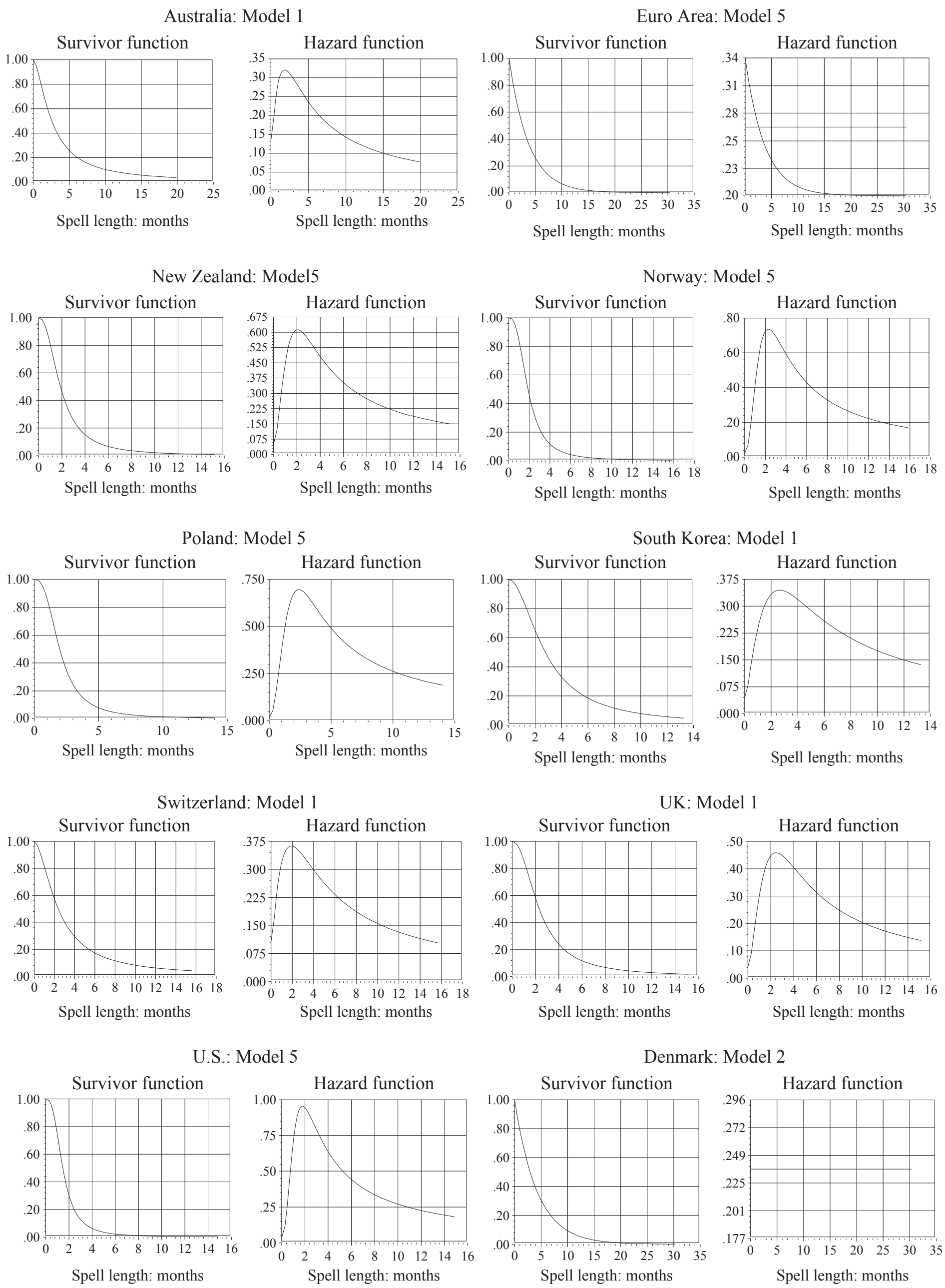
model outperforms the lag-based Taylor rule for Australia, South Korea, Switzerland, and the UK, while the lag-based Taylor rule model is the most preferred in Euro Area, New Zealand, Norway, Poland, and the U.S.. Denmark is the only country with the characteristic of interest rate smoothing, because the regressor Interest_{t-1} is statistically significant only for Denmark. Neither exchange nor unemployment rate is a significant determinant of the interest rate spell for any of the ten countries (or area), which is consistent with the result of Shih and Giles (2009). The survivor and hazard functions of the best models are plotted in Figure 2. Similar to the non-parametric analysis, the slope of survivor functions declines at a decreasing rate. The hazard functions for Euro Area and Denmark are constant, while exhibit an inverted U-shape for the other countries.

V. *Conclusion*

In this study a duration analysis is adopted to examine the determinants of interest rate spells for ten countries (or area) among which eight countries adopt the inflation targeting policy and two do not. The results show that the length of the interestrate spell is affected by the inflation rate and the growth rate of GDP, and both the simple and lag-based Taylor rules explain the data well. However, neither exchange nor unemployment rate is significant in determining the interest rate spell. Denmark is the only country with the characteristic of interest rate smoothing. Hence, the empirical outcomes present evidence that central banks usually implement their interest rate policies in accordance with the Taylor Rule[7].

[7] work in progress considers situations where the data series contains one or more break points by adapting methods of Ho and Wan (2002) or Zhou et al. (2010).

FIG. 2. Survivor and hazard functions under the preferred parametric distribution[8]



[8] The best model specification for the Euro Area and Denmark is exponential; while the log-logistic model is the most suitable for the other eight.

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