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Nonlinear Cointegration Relationships Between Non-Life Insurance Premiums and Financial Markets

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Abstract

The aim of this article is to study the adjustment dynamics of the non-life insurance premium (NLIP) and test its dependence to the financial markets in five countries (Canada, France, Japan, the United Kingdom, and the United States). First, we justify the linkage between the insurance and the financial markets by the underwriting cycle theory and financial models of insurance pricing. Second, we examine the relationship between the NLIP, the interest rate, and the stock price using the recent developments of nonlinear econometrics. We use threshold cointegration models: the switching transition error correction models (STECM). We show that STECM perform better than a linear error correction model (LECM) to reproduce the NLIP dynamics. Our empirical results show that the adjustment of the NLIP in France, Japan, and the United States is rather discontinuous, asymmetrical, and nonlinear. Moreover, we suggest a strong evidence of significant linkages between insurance and financial markets, show two regimes for the NLIP, and find that the NLIP adjustment toward equilibrium is time varying with a convergence speed that varies according to the insurance disequilibrium size.

Introduction

Several theoretical and empirical studies focused on the explanation of the fluctuations of premiums and profits in the insurance industry and concluded there is a cyclical movement in insurance dynamics (Winter, 1994; Harrington and Niehaus, 2000). In such a context, these studies showed that the underwriting cycle, largely

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observed in the United States, could exist in other developed countries because of the proliferation of international reinsurance services (Cummins and Outreville, 1987; Cummins and Patricia, 1997), the integration of financial markets (SwissRe, 2001), and the interdependence of economic activities (Leng and Meier, 2006). According to these studies, the average cycle period is about 6–8 years, but this period generally varies across lines and among countries.

Besides, the causes of this underwriting cycle were the subject of several studies that developed many explanations in the literature. Among these explanations, we retain: (1) the rate-making process (Venezian, 1985); (2) the capacity constraints (Gron, 1994) and the institutional, regulatory, and accounting characteristics (Cummins and Outreville, 1987; Lamm-Tennant and Weiss, 1997); (3) the fluctuations of interest rates (Doherty and Garven, 1992; Fields and Venezian, 1989; Haley, 1993; Fung et al., 1998; Leng and Meier, 2006; Meier and Outreville, 2006); and (4) the fluctuations of stock markets (Cummins and Nye, 1980; Lamm-Tennant and Weiss, 1997; Chen et al., 1999). In this article, we focused our study on the exploration of the elements (3) and (4) while examining the non-life insurance premium (NLIP).

In practice, the empirical studies that focused on this topic and on the study of the possible linkages between financial markets and insurance markets are not numerous in the literature. Doherty and Garven (1992), Fields and Venezian (1989), Smith (1989), and Fung et al. (1998) showed that changes in insurance premiums are related to those in interest rates, whereas Lamm-Tennant and Weiss (1997) and Chen et al. (1999) retained changes in stock market returns to explain the NLIP fluctuations. Formally, this implied two types of approaches. On the one hand, most of the authors considered the series in the first difference and studied only the short-term adjustment dynamics of insurance premiums. On the other hand, other studies used the linear cointegration framework, which enables examination of the relationship between the NLIP and interest rates in the long term (Haley, 1993; Grace and Hotchkiss, 1995; Leng and Meier, 2006; Meier and Outreville, 2006). Using the same framework, Blondeau (2001) studied the relationship between stock market returns and the insurance premium. In this article, we first studied the linkages between the NLIP, interest rates, and stock prices for five countries (Canada, France, Japan, the United Kingdom, and the United States) and we showed strong evidence of linear cointegration relationships between insurance and financial markets for all of these countries. Nevertheless, using linear modeling techniques only supposes that the NLIP adjustment dynamics are necessarily continuous, symmetrical, and linear with an invariant adjustment. However, these dynamics are not usually checked in practice; thus, these previous empirical results and conclusions have to be carefully reconsidered.

Indeed, the adjustment dynamics of the NLIP may be variable, discontinuous, asymmetrical, and nonlinear. This is notably due to the competitive aspect between insurers and to the coexistence of heterogeneous expectations from insurers who assume different and distinct costs. In such a context, Higgins and Thistle (2000) recently showed that the insurance market behaves differently in the different phases of the underwriting cycle. This is due to the fact that insurers are not necessarily identical and do not face identical regulatory constraints. More precisely, insurers differ in the amount of excess capacity that they hold and they face different state-level regulatory constraint. Leng et al. (2002) also found that the interest rate series and underwriting margins are characterized by regime changes. The NLIP adjustment is *a priori* smooth, asymmetrical, and nonlinear because after an exogenous shock, the insurers may immediately react but they will not necessarily respond at the same time, thus inducing some persistence in the premium dynamics. Besides, the insurers' behaviors and expectations are not homogeneous and their costs and their degree of competition and power are not identical either. This double heterogeneity seems to justify the abnormal, asymmetrical, and nonlinear character of the NLIP dynamics and it implies that a nonlinear time-varying process reproducing the NLIP adjustment dynamics should be considered.

The purpose of this article is then twofold. First, we examine the empirical relationship between the NLIP, the interest rate, and the stock index in five developed countries (Canada, France, Japan, the United Kingdom, and the United States) within a nonlinear framework, both in the short and long terms. Second, using the recent developments of nonlinear econometrics, we check whether the NLIP adjustment dynamics are nonlinear. So, the originality of this article is also twofold. On the one hand, this article considers both the interest rate and the stock price to study the effect of financial markets on the NLIP and to measure the causality relationships between insurance and financial markets using nonlinear modeling. On the other hand, to our knowledge, this study is the first to use the nonlinear cointegration techniques to reproduce the insurers' behavior in a multivariate and international context.

This article is organized as follows. The following section briefly reviews the previous theoretical and empirical studies focusing on NLIP modeling and on the relationship between the NLIP, interest rates, and stock market returns. The next section presents the econometric model and the nonlinear methodology. Empirical results are discussed in the following section, while the last section concludes the article and highlights some possible extensions.

A BRIEF LITERATURE REVIEW

To begin with, we may note that all developed models in the insurance literature are extensions of the financial asset pricing models. The best-known model is the insurance capital asset pricing model (CAPM), which can be defined, following Fairley (1979), as[1]

$$r_u = -r_f + \beta_u(r_m - r_f), \tag{1}$$

where r_u is the underwriting return, r_f is the risk-free interest rate, $(r_m - r_f)$ is the risk premium, and $\beta_u = \frac{\text{cov}(r_u, r_m)}{\text{var}(r_m)} = \frac{\sigma_{r_m}}{\sigma_{r_u}}\text{corr}(r_u, r_m)$.

The underwriting return is defined as

$$r_u = \frac{P - L - E}{P}, \tag{2}$$

[1]There are other models of insurance pricing, such as the discounted cash flow model and the option pricing model. For a complete literature review on financial models of insurance pricing, see Cummins (1991).

where P designates the non-life premiums, L represents the losses, and E represents the expenses.

If we assume that $\beta_u(r_m - r_f)$ is constant, as in Leng and Meier (2006), or more precisely that the expected premium $\beta_u^a(r_m^a - r_f)$ is constant over time, we get

$$\frac{P - L - E}{P} = -r_f + c \Leftrightarrow P = \frac{L + E}{(1 + r_f - c)}. \tag{3}$$

This shows an inverse relationship between the premium and the interest rate. But if $\beta_u(r_m - r_f)$ is not constant over time, we obtain

$$P = \frac{L + E}{[1 + (1 + \beta_u)r_f - \beta_u r_m]}. \tag{4}$$

This relation also confirms the inverse relation between the NLIP and r_f, provided that $(1 + \beta_u) > 0$. Moreover, P increases with r_m and/or (r_m^a) if $\beta_u > 0$ and/or $(\beta_u^a > 0)$, and decreases with r_m and/or (r_m^a) if $\beta_u < 0$ and/or $(\beta_u^a < 0)$.

Then, Moridaira et al. (1992) developed a modified CAPM, which integrates the financial assets and insurance. They showed that the purchase of insurance should not be ignored in determining the equilibrium rate of asset return.

Empirically, some authors examined the relationship between premiums, interest rates, and stock market returns. For example, Doherty and Kang (1988) suggested that underwriting cycles may be related to interest rate cycles. Fields and Venezian (1989) showed that over the period 1960–1985, the profitability was related to the unexpected interest rates. Smith (1989) found a strong relationship between the loss ratio and the bond yield over the period 1950–1982. Two later studies, which also examined the relationship between premiums and interest rates for the period 1946–1988, are proposed by Niehaus and Terry (1993) and Fung et al. (1998). The first study, using Granger causality tests, showed that premiums are not related to the return of Treasury bills. The second one developed an impulse response analysis by estimating a vector autoregressive (VAR) model and found that the interest rate explains a substantial proportion of premium variations.[2]

Other authors attributed the underwriting cycle to stock market fluctuations. For example, Cummins and Nye (1980) examined the relationship between the combined ratio and the return on the market portfolio of common stocks from 1958 through 1976. They found no significant relationship between these variables and concluded that the dynamics of combined ratios are either purely random or are subject to common influences independent of the factors affecting stock markets. In an international framework, Lamm-Tennant and Weiss (1997) analyzed the relationship between changes in premiums, changes in discount rates, and changes in stock indexes in the United States, Canada, West Germany, Italy, Switzerland, Spain, Denmark, and Japan for the period 1971–1987. They estimated a pooled cross-section time series model and

[2]Fung et al. (1998) considered two types of interest rates: monthly Treasury bill and Treasury note rates.

showed that changes in premiums are negatively related to changes in stock indexes but not to changes in the discount rate. Then, they estimated again the relationship for individual countries while using the generalized least squares method. Their results showed that changes in premiums are negatively related to changes in stock indexes and to changes in discount rate only for the United States and Canada. Nevertheless, for West Germany and Italy, they found no significant relationship between these variables. For Japan, however, they found that changes in premiums are positively related to changes in stock indexes but not to changes in the discount rate. This was also obtained by Chen et al. (1999) for Japan over the period 1970–1995.

Nevertheless, as we noted before, these studies either considered the series in their first difference and consequently captured only the short-term dynamics of the premium, or they examined the relationship between premiums and interest rates, using linear cointegration techniques, which reproduces long- and short-term dynamics but only in a linear framework. For example, Haley (1993) found that the underwriting margin and the 90-day Treasury bill rates are linearly cointegrated and negatively related over the period 1930–1989. Grace and Hotchkiss (1995), using quarterly data from 1974 through 1990, showed that there is a positive long-run relationship between the combined ratio and the short-term interest rate, although they had suggested that there was no significant relationship between these variables in the short term. Leng et al. (2002) examined the relationship between underwriting profits and investment income from 1958 to 1999.[3] While considering two periods (before and after 1981), they showed no cointegration relationship between these variables for the first period (1958–1981) and accepted the cointegration hypothesis for the second period. Yet, this may not indicate any switching regime or structural break in the premium dynamic.

Blondeau (2001), using a VAR cointegration analysis, also found a long-term relationship between the NLIP, long-term interest rates, and stock market returns over the period 1963–1999. Her results showed that changes in premiums are only related to those in interest rates and only in the short term. More recently, Leng and Meier (2006) and Meier and Outreville (2006) also rejected the linear cointegration relationship between the loss ratio and interest rates.[4] The former showed that the loss ratio and interest rates of Germany, Japan, Switzerland, and the United States, respectively, for the periods 1955–1991, 1968–1997, 1968–1997, and 1955–1997 present breaks in different years, and the authors demonstrated that these variables are not cointegrated. The second authors examined the relationship between the loss ratio and the money market rate for France, Germany, and Switzerland for a more recent period (1982–2001). They suggested a positive and significant relationship only for Germany.

Nevertheless, it is important to note that the modeling techniques used for these studies are based on restrictive hypotheses such as that of linearity. Indeed, all authors supposed that the premium adjustment dynamics are linear and symmetrical. Furthermore, they admitted that premiums are generated by stochastic process with time-invariant parameters. However, these hypotheses are questionable for many

[3]According to Leng et al. (2002), $E(r_u) = -a(t)r(t) + b(t)$.
[4]The loss ratio is defined as follows: $LR = \frac{L}{P}$.

reasons. Indeed, due to the presence of frictions in the insurance market, the heterogeneity of insurers' expectations, the competition between insurers, and a strong interdependence between insurance markets, the insurance premium dynamics seem to be asymmetrical, discontinuous, and nonlinear with a time-varying adjustment speed. Besides, Higgins and Thistle (2000), considering a smooth transition regression (STAR) model, showed that the underwriting profits follow a stochastic process with time-varying parameters. More recently, Venezian (2002) also suggested that the use of linear cointegration to relate underwriting income to interest rates is misspecified since the coefficient of the interest rate normally varies over time.

In order to remedy these limits, following Higgins and Thistle (2000), we propose to extend the study of the NLIP adjustment dynamics to a nonlinear framework. In this article we offer a new methodology for the reproduction of the NLIP adjustment dynamics while referring to threshold cointegration, and we also use a particular switching transition error correction model (STECM). The use of the STECM not only allows us to reproduce the possible nonlinearities and asymmetries inherent in the NILP adjustment dynamics but also to characterize the linkages between insurance and financial markets per regime. Moreover, it helps us to characterize more precisely the evolution of the insurance industry and to understand more explicitly the insurer's behaviors and policies. The following section presents the STECM methodology and briefly describe its main stages of modeling.

NONLINEAR COINTEGRATION

Linear Cointegration and LECM

The cointegration theory was introduced by Granger (1981), developed by Granger (1986), Engle and Granger (1987) and Johansen (1988) among others. According to this theory, a nonstationary series in level can enter a stable linear relationship, which plays the role of a long-run target influencing short-run fluctuations[5].

Concerning the NLIP modeling, under the null hypothesis of linearity, the NLIP adjustment is said to be symmetrical and linear and its dynamics can be reproduced through the following LECM

$$\Delta Y_t = \theta_0 + \rho \hat{z}_{t-1} + \sum_{i=1}^{p} \theta_{1,i} \Delta Y_{t-i} + \sum_{j=0}^{p} \theta_{2j} \Delta X_{1,t-j} + \sum_{l=0}^{p} \theta_{3,l} \Delta X_{2,t-j} + \varepsilon_t, \quad (5)$$

where Y_t, $X_{1,t}$, and $X_{2,t}$ are, respectively, the NLIP in logarithm, the stock price also in logarithm, and the interest rate.

[5]Let $X_t' = (X_{1,t}, X_{2,t})$ and Y_t be nonstationary in level but stationary in first difference; they are then integrated of order one (I(1)) and they are said to be cointegrated if there is a linear combination between these variables ($\hat{z}_t$), which is stationary. This combination corresponds to: $\hat{z}_t = Y_t - \hat{\alpha}_0 - \hat{a}_1 X_{1,t} - \hat{a}_2 X_{2,t}$. $\hat{z}_t$ is usually interpreted as the equilibrium error that measures the current deviation from the so-called long-run equilibrium: $\hat{z}_t = Y_t - \hat{\alpha}_0 - \hat{a}_1 X_{1,t} - \hat{a}_2 X_{2,t}$. According to the error-correction mechanism (Engle and Granger, 1987), its lagged value $\hat{z}_{t-1}$ determinates the disequilibrium size and the adjustment speed and it influences the variations ΔY_t – in addition to the lagged first differences of the variables $\Delta X_{1,t-j}$, $\Delta X_{2,t-l}$ and ΔYi, $\forall\, i \geq 1$, $j \geq 0$, and $l \geq 0$.

However, this type of specification assumes that the adjustment to the long-run equilibrium is linear and continuous with a constant adjustment speed measured by the coefficient ρ. An LECM extension can enable the NLIP adjustment to be nonlinear with a time-varying adjustment speed. More particularly, introducing the hypotheses of nonlinearity and switching regimes to the LECM specification implies a nonlinear framework given by the STECM. The STECM were introduced and used for the first time by Van Dijk and Franses (2000), and their modeling steps were explicitly developed by Van Dijk et al. (2002).

In the next section, we focus on the STECM modeling for which the equilibrium is assumed to be linear, unique, and provided by the linear cointegration relationship between the NLIP and financial variables. However, the originality of this specification is to enable the NLIP adjustment to be nonlinear and asymmetrical with time-varying adjustment speed. This speed varies depending on the size of the disequilibrium given by the spread between the NLIP deviation and the threshold or by the disequilibrium resulted from the financial and insurance variables.

STECM

Threshold cointegration models were introduced by Balke and Fomby (1997) and generalized by Anderson (1997) and Van Dijk et al. (2002) to take smoothness into account in the adjustment. They were used by, among others, Anderson (1997), Balke and Fomby (1997), Escribano (1997), Van Dijk and Franses (2000), Rothman et al. (2001), Dufrénot and Mignon (2002), Jawadi and Koubbaa (2004), Jawadi (2006), and Jawadi and Prat (2008). These studies often analyzed the adjustment dynamics of several financial variables and reproduced the nonlinearities and discontinuities induced by financial market frictions. Indeed, the main advantage of this modeling is to enable the adjustment to be discontinuous, asymmetrical, and active per regime. It defines an on-off adjustment dynamic process that depends on the sign and/or the size of the disequilibrium and the deviation between potential profits and assumed costs. Yet, this modeling has never been applied to insurance markets.

For instance, Escribano (1997) checked the nonlinear adjustment mechanism for the money demand of the United Kingdom over the period 1878–1970. Rothman et al. (2001) estimated an STECM to account for the relations between the production and the money demand. Anderson (1997) and Michael et al. (1997) showed that these models provide a good description of financial asset dynamics in presence of transaction costs. Jawadi (2006) and Prat and Jawadi (2008) also showed the superiority of the STECM over the LECM in reproducing stock price adjustment toward the fundamental value. The main idea of the threshold modeling is that the adjustment is active per regime, since the possible stock price deviations toward equilibrium may create some arbitrage opportunities and imply adjustment, but it may also constrain stock prices to adjust when these deviations are not enough to offset the transaction costs.

Overall, these studies highlighted the superiority of threshold modeling when studying the adjustment dynamics of financial assets and they differently justified the nonlinearity. Most of the economic justifications for nonlinearity are the coexistence of heterogeneous investors' expectations (De Grauwe and Grimaldi, 2005), the presence of different transaction costs (Anderson, 1997; Dumas, 1992), mimetic behaviors

(Orléan, 1990), and the existence of stock market frictions, which may imply some smoothness, persistence, discontinuities, structural breaks, inertia effects, and asymmetry in the adjustment dynamics. Such stylized facts also characterize the insurance market. Indeed, the asymmetries can be explained either through the presence of insurers who do not necessarily react in the same way to shocks of different nature and sign or through the fact that insurers do not necessarily have the same information so that they may hesitate in their choices when facing different costs and shocks. As a result, they act on the market only when they expect future profits to exceed the assumed costs. To reproduce this behavior, the STECM offers a relevant formal framework since it enables the adjustment and arbitrage to be active per regime and allows the intensity of the error-correction mechanism to vary according to the sign and/or the size of the deviation from the equilibrium.

In practice, this asymmetry characterizing NLIP deviations from the equilibrium may be understood using the STECM that incorporates the delayed error-correction term z_{t-d} as a transition variable of the transition function.[6] More particularly, the degree of asymmetry is captured by the transition function distribution, which depends on the disequilibrium size. The latter is measured by the spread between the delayed error-correction term or transition variable z_{t-d} and the threshold that is defined by the insurers' costs and depends on financial variables. Concerning the type of asymmetry captured by the STECM, it depends on whether the transition function type is logistic or exponential.[7] The logistical function reproduces the asymmetry in the sign of the NLIP deviations, whereas the exponential function captures the asymmetry inherent to the size of NLIP deviations. More precisely, in the logistical case, when z_{t-d} increases, the mean reversion mechanism of the NLIP toward equilibrium becomes more efficient and the corresponding adjustment speed increases. The convergence speed depends on the sign of NLIP deviations and belongs to the interval [ρ_1, $\rho_1 + \rho_2$], where ρ_1 and ρ_2 designate, respectively, the adjustment terms in the first and the second regimes of NLIP dynamics. For the exponential transition function, the adjustment is stronger and higher as z_{t-d} is rising. More particularly, the convergence speed or the adjustment coefficient varies, from $\rho_1 + \rho_2$ to ρ_1 when z_{t-d} increases. Therefore, independently of the transition function, the main advantage of the STECM modeling is its capacity to specify a time-varying NLIP dynamic that is more appropriate than that issued from the LECM.

Formally, the STECM constitutes an extension of the LECM to the nonlinear framework. For example, a two-regime STECM can be defined as a combination of two LECM insofar as it integrates two adjustment terms. The first one (ρ_1) measures the degree of adjustment in the first regime whereas the second one (ρ_2) replicates the intensity of error correction in the second regime. More precisely, the extension to the nonlinear framework is made through the introduction of a nonlinear component defined as the product of a transition function and the adjustment term of the second regime.

[6] d is the delay parameter.

[7] These two types of transition function were described by Teräsvirta and Anderson (1992) and they are the most used functions, but of course, they can be extended to other transition function families.

As in Jawadi (2006) and Jawadi and Prat (2008), a two-regime STECM is described as follows:

$$\Delta Y_t = \theta_0 + \rho_1 \hat{z}_{t-1} + \rho_2 \hat{z}_{t-1} \times F(z_{t-d},\gamma,c) + \sum_{i=1}^{p} \theta_{1,i} \Delta Y_{t-i} + \sum_{j=0}^{p} \theta_{2,j} \Delta X_{1,t-j} + \sum_{l=0}^{p} \theta_{3,l} \Delta X_{2,t-l} + \varepsilon_t, \quad (6)$$

where Y_t is the NLIP in logarithm; $X_{1,t-j}$ is the lagged stock price in logarithm; $X_{2,t-l}$ designates the lagged interest rate; z_{t-1} is the error-correction term; z_{t-d} is the transition variable; $F(.)$ is the transition function; γ and c are, respectively, the transition speed ($\gamma > 0$) and the threshold parameters; ρ_1 and ρ_2 are, respectively, the adjustment terms in the first and the second regimes; $\theta_{1,i}$, $\theta_{2,j}$, and $\theta_{3,l}$ are the AR parameters; and ε_t is distributed as i.i.d.

According to Teräsvirta and Anderson (1992), Granger and Teräsvirta (1993), and Teräsvirta (1994), F can be either exponential or logistic. This choice may enable us to reproduce two types of asymmetry (in our case: asymmetry due to the change of the NLIP deviation signs and asymmetry associated to the variation of the NLIP deviation size) with a simple transition function.[8] A first-order logistical transition function is given by

$$F(z_{t-d},\gamma,c) = [1 + \exp\{-\gamma(z_{t-d} - c)\}]^{-1}, \quad (7)$$

while a first-order exponential transition function is defined as

$$F(z_{t-d},\gamma,c) = 1 - \exp\{-\gamma(z_{t-d} - c)^2\}. \quad (8)$$

Systems (6, 7) and (6, 8) define, respectively, the LSTECM (logistic STECM) and the ESTECM (exponential STECM) models.[9] As discussed above, the LSTECM is useful to replicate the asymmetric adjustment dynamics due to a sign change of the NLIP deviation, whereas the ESTECM is used to reproduce the asymmetric adjustment dynamics in the NLIP size of positive or negative deviations. Thus, the ESTEC representation is able to replicate the asymmetry due to the size effect, which can be induced by the presence of different frictions on the insurance market and by the coexistence of distinct costs, decisions, and policies in insurance companies. Two insurance premium dynamics or regimes may then be distinguished. The first regime is characterized by NLIP deviations that are small, near unit root, and random. However, in the second regime, the NLIP deviations are rather large, nonlinearly mean reverting toward equilibrium, and similar to white noise.

[8]For more details on the types of asymmetry reproduced by the ESTECM, see, among others, Jawadi (2006, chaps. 2 and 4).

[9]According to Timo Teräsvirta, logistic and exponential functions are just simple transition functions, but of course the exponential function, for example, can be another distribution in the exponential family.

In this article, we centered our study on the ESTECM since our article essentially aims at examining the modeling nature of the NLIP adjustment dynamics relative to financial markets but independent of the signs of NLIP deviations toward equilibrium. Besides, the ESTECM is the model that is the most frequently used, more particularly, for the reproduction of the adjustment dynamics of financial asset prices (see Jawadi, 2006, chap. 3).

ESTECM Modeling

In practice, the modeling stages of the ESTECM are similar to those of the ESTAR (exponential STAR) model that were developed by Granger and Teräsvirta (1993) and Teräsvirta (1994). The only difference concerns the transition variable, which may be a lagged endogenous variable or an exogenous variable for the ESTAR model, whereas it is given by the lagged error-correction term (z_{t-d}) in the ESTECM. The specification of the ESTECM is based on the LECM specification. Indeed, it requires the definition of the explanatory variables, the determination of the delay number (p) of these explanatory variables, and linearity tests. The estimation of the ESTECM is carried out using the nonlinear least squares (NLS) method, which is equivalent to the almost-maximum likelihood method. This method is based on a nonlinear optimization process that requires the ESTECM parameters to be initialized. To achieve this, we retain the estimators of the LECM as initial values of the AR parameters of the ESTECM. For what is, according to Teräsvirta (1994), the most problematic estimator (γ), we first divide it by the variance of the transition variable to ensure the algorithm convergence. This implies a value of γ around 1. Second, we estimate the ESTECM by the NLS method. Then, we vary γ around 1 and we reestimate the ESTECM again until its estimators do not vary anymore, suggesting that the maximum is absolute and not local.[10] In the next section, we focus on the empirical modeling of the ESTECM.

Empirical Results

Data

The main objective of our empirical study is to examine the NLIP adjustment dynamics while using nonlinear modeling techniques. In particular, we test whether the NLIP is related to interest rates and stock markets in a nonlinear framework and we analyze how insurers adjust their decisions according to the under- and overvaluation movements of the financial market. This is the most important and interesting element for at least two reasons. On the one hand, our results would certainly be helpful to understand the insurer's behaviors, decisions, rules, and policies more rigorously and to foresee his reaction in periods of economic and financial recession and/or expansion. It would also help us to comprehend the cyclical movements of the insurance market. On the other hand, using the recent developments of nonlinear econometrics and a threshold specification of the possible linkages between financial and insurance markets that are not activated all the time should be useful enough to specify the determinants of the insurer's prices per regime. It should also precisely determinate the contribution of the insurance fundamental and that of financial markets to the definition of insurance premiums.

[10]For more details on the ESTECM modeling, see Jawadi (2006) and Jawadi and Prat (2008).

TABLE 1
Data

Countries	Period	Number of Observations
Canada	1969–2005	37
France	1960–2005	46
Japan	1966–2005	40
United Kingdom	1965–2005	41
United States	1954–2005	52

To do so our empirical application focuses on the non-life insurance markets of five countries (Canada, France, Japan, the United Kingdom, and the United States) that have the most developed NLIP markets. All of the data are annual and cover the period 1969–2005 for Canada, 1960–2005 for France, 1966–2005 for Japan, 1965–2005 for the United Kingdom, and 1954–2004 for the United States. Perhaps, it would be more interesting to retain the same period for all countries. Yet this is not the case in this article, which may be justified in many ways. First, the number of observations is relatively low, so when data are available for a long period, we prefer to retain them in order to get the highest number of observations. Second, for each country, we estimate a univariate model and under the null hypothesis of linearity, the NLIP dynamic is reproduced using a univariate autoregressive (AR) model and not a vectorial AR (VAR) model. These data are presented in Table 1.

For insurance data, we used the direct written premiums that we got from the database of SwissRe (Swiss Reinsurance Company).[11] For interest rates, we considered the government bond yield series, which are, as well as stock indexes, collected from Datastream. All variables are transformed in logarithm, except interest rates, in order to reduce their variations over the studied periods. All data are nominal. We preferred nominal data to real data for two reasons. First, nominal data refer to information recorded at current prevailing prices and reflect changes in volume and in prices, whereas information is recorded at constant-year price for real data. Since the inflation rate for most countries was relatively stable in the studied period, it may not have affected the results. Second, a study of the evolution of premium dynamics over time using nominal data could be more interesting since this would enable us to compare our results to those of other empirical studies also using nominal data.

Then, in order to have a first explicit idea about the NLIP dynamics, we plotted the graphics of the NLIP growth rates in the appendices (Figure A1 in Appendix A). The preliminary analysis of these graphics suggested significant asymmetry between the expansion and recession phases of NLIP and showed an important cyclical movement characterizing the NLIP dynamics of the most countries. More precisely, we identified several phases of positive and negative NLIP growth rates as well as many

[11]Due to a data constraint, we used the written premiums instead of the earned premiums. Niehaus and Terry (1993), Lamm-Tennant and Weiss (1997), Fung et al. (1998), Chen et al. (1999), and Blondeau (2001) also used the written premiums in explain the cyclical movements inherent in insurance premiums.

periods of increase and decrease of the NLIP. The phases of expansion may be associated with the periods of tension during which premiums should increase, whereas decreasing phases correspond to periods of recession that induce the reduction of the NLIP (Bruneau and Sghaier, 2008), among others.

In the insurance literature, as suggested before, several explanations were developed to explain this cyclical movement characterizing the premium dynamic. On the one hand, Venezian (1985), among others, retained the hypothesis of extrapolative rating, according to which insurers forecast the damages to come according to past damages. This reasoning may imply a cyclical premium and rating. On the other hand, Winter (1988), Gron (1994), and Harrington (2000), among other authors, explained the cyclical fluctuations of premiums in terms of constraint capacity. Indeed, the evolution of insurer's capitals and the alternation of periods of capital excess and insufficiency can induce cyclical movements in premiums.[12] Others studies attributed the cyclical behavior of insurance premiums to the strong interdependence between financial markets and the insurance industry and explained the premium adjustment through the dynamic evolution of financial markets.

However, empirically, the study of NLIP dynamics is not developed enough and the modeling of their cyclical behavior within a nonlinear framework still has to be performed. This article is mainly interested in carrying out an empirical study of NLIP dynamics while taking into account the linkages between financial and insurance markets and checking the cointegration relationships between the NLIP, the interest rate, and the stock price. Although it focuses on insurance premiums, this study is not only interesting for insurers but also for all financiers. Indeed, given the strong linkages between financial and insurance markets, the knowledge and characterization of the NLIP helps to forecast the future movement of financial markets.

Unit Root Tests

Stationarity is not only required to check the cointegration hypothesis between the NLIP and financial variables but also necessary for the implementation of the linearity tests. Thus, we applied several unit root tests in order to explore the stationarity properties of our studied series before checking the cointegration properties between the series of interest, and we present the results of these unit root tests in Table 2.

First, we applied the ADF tests of Dickey–Fuller tests (1979, 1981). These tests showed that all series are not stationary in level, but stationary in the first difference in all studied countries, indicating that the NLIP, stock indexes, and interest rates are therefore integrated of order one: I(1). Second, while applying the unit root tests of Phillips and Perron (1988), noted PP, which are more robust to autocorrelation and heteroskedasticity, we supported the results of the ADF tests. Third, we applied the ADF-GLS tests of Elliot et al. (1996). These tests are closely similar to the ADF tests, as a GLS detrending is applied before testing the detrended series via the DF representation. However, the ADF-GLS tests are more powerful than the ADF tests

[12]For more details on the explanations of subscription cycles of non-life insurance, see Bruneau and Sghaier (2008).

Table 2
Unit Root Tests

		ADF		PP		ADF-GLS[b]		KPSS				Z&A	
								Level		Δ			
	Series	Level	Δ	Level	Δ	Level	Δ	l_4	l_{12}	l_4	l_{12}	Level	Δ
Canada	Y	6.05[a]	−2.79[a]	5.46[a]	−2.65[a]	0.184	−4.49	0.15[c]	0.17[c]	0.33[b]	0.32[b]	−4.03	−4.91
	X_2	−0.67[a]	−4.65[a]	−0.67[a]	−4.62[a]	−0.79	−4.63	0.15[c]	0.16[c]	0.30[b]	0.29[b]	−4.41	−4.92
	X_1	−3.23[c]	−5.99[b]	−3.29[c]	−6.01[b]	−1.04	−5.65	0.16[c]	0.30[c]	0.14[b]	0.36[b]	−4.40	−4.92
France	Y	1.46[a]	−3.74[a]	0.09[c]	−3.74[c]	−0.32	−2.08	1.2[b]	0.56[b]	0.43[b]	0.36[b]	−4.40	−5.51
	X_2	−0.55[a]	−4.8[a]	−0.61[a]	−4.79[a]	−1.4	−4.79	0.29[b]	0.56[b]	0.29[b]	0.31[b]	−4.34	−5.0
	X_1	−2.86[b]	−4.49[a]	1.93[a]	−4.48[a]	0.31	−4.61	1.14[b]	0.52[b]	0.18[b]	0.22[b]	−4.37	−5.31
Japan	Y	2.08[a]	−2.17[a]	−1.63[b]	−3.71[a]	0.20	−2.64	1.03[b]	0.49[b]	0.28[b]	0.35[b]	−3.98	−6.97
	X_2	−3.25[c]	−5.1[a]	−2.42[c]	−4.33[a]	−0.9	−4.55	0.19[c]	0.15[c]	0.13[b]	0.24[b]	−4.16	−5.47
	X_1	1.32[a]	−5.24[a]	1.14[a]	−5.29[a]	−0.72	−3.22	0.82[b]	0.47[b]	0.38[b]	0.32[b]	−4.32	−6.15
U.K.	Y	−2.17[b]	−5.24[b]	−2.1[b]	−5.24[b]	−0.32	−5.09	1.1[b]	0.52[b]	0.43[b]	0.34[b]	−2.75	−6.44
	X_2	−0.52[a]	−4.45[a]	−0.93[b]	−4.26[b]	−0.59	−2.67	0.52[b]	0.72[b]	0.38[b]	0.31[b]	−4.1	−6.1
	X_1	2.14[a]	−6.52[a]	−0.64[b]	−7.59[b]	0.11	−6.85	1.1[b]	0.51[b]	0.10[b]	0.12[b]	−4.71	−7.31
U.S.	Y	3.24[a]	−3.88[b]	−1.31[b]	−3.35[b]	0.11	−4.10	1.4[b]	0.58[b]	0.26[b]	0.22[b]	−3.94	−4.61
	X_2	−0.34[a]	−6.1[a]	−0.38[a]	−6.05[a]	−1.03	−5.9	0.48[b]	0.73[b]	0.33[b]	0.32[b]	−4.17	−5.15
	X_1	3.02[a]	−6.57[a]	3.55[a]	−6.59[a]	1.42	−6.79	1.24[b]	0.54[b]	0.22[b]	0.17[b]	−3.75	−8.07

Notes: Y, X_1, and X_2 designate, respectively, the NLIP in logarithm, the stock price in logarithm, and the interest rate. Level and Δ designate, respectively, series in level and those in the first difference. l_4 and l_{12} are the values suggested by Schwert (1989) for the truncation parameter for the KPSS test:

$$l_4 = \mathrm{int}\left[4\left(\frac{T}{100}\right)^{\frac{1}{4}}\right] \text{ and } l_{12} = \mathrm{int}\left[12\left(\frac{T}{100}\right)^{\frac{1}{4}}\right]$$

where T is the number of observations and int [.] denotes the interior part.

[a]Model with neither trend nor constant.

[b]Model with constant but without trend and (c) model with trend and constant. The critical values for the ADF and PP tests at the 5% statistical level are −1.95 for model (a), −2.89% for model (b), and −3.45 for model (c).

[c]The critical values for the KPSS tests at the 5% are 0.463 and 0.146 for, respectively, the model without trend (b) and the model with trend (c). Finally, the critical value for the test of Zivot and Andrews (1992), noted Z&A, is −4.42% at the 5% statistical level.

in terms of small sample size. The results of the ADF tests were also confirmed by the ADF-GLS tests. Fourth, we implemented a more powerful test: the KPSS test of Kwiatkowski et al. (1992), which tests the null hypothesis of stationarity against its alternative of unit root. The KPSS test also indicated that, at the 5 percent statistical level, all series contain a unit root in the level whereas these series are stationary in the first difference. Finally, even though all these unit root tests yielded similar results, we applied the unit root test of Zivot and Andrews (1992), noted Z&A. This test allows for the presence of a structural break, which may affect the stationarity properties of the series, since a structural break can bias the usual unit root test. The advantage of this test in relation to Perron test is that the break point is estimated rather than exogenously fixed. According to the results of the Z&A test, we also retained that the NLIP, interest rates, and stock prices are I(1), even though they accounted for an endogenously estimated structural break.

Overall, the convergence of these different unit root tests enables us to conclude with a certain degree of certainty that all studied series are I(1). Therefore, these series could be linearly cointegrated if a linear combination of these variables is obtained and is stationary. In the next step, it would be significant to check the hypothesis of cointegration between the NLIP, interest rates, and stock prices.

Linear Cointegration Tests

First, we estimated the long-run relationship while regressing the NLIP on a constant, the stock market index, and the interest rate in Equation (9) and we retained the estimated residual of this relation ($\hat{z}_t$).

$$Y_t = \alpha_0 + \alpha_1 X_{1,t} + \alpha_2 X_{2,t} + z_t, \tag{9}$$

where Y_t and X_{1t} are, respectively, the NLIP and the stock price in logarithm, and X_{2t} is the interest rate.

The results, which are presented in Table 3, show significant long-term relationships between the NLIP, interest rates, and stock prices for all studied countries. Indeed, the estimated coefficients of interest rate and stock price are statistically significant at 5 percent for all countries. This strong statistical significance can reflect the important linkages between insurance and financial markets. Indeed, the insurance industry is very important and promising for the latter since it covers their risks and protects the economy from losses due to accidents and damages.

TABLE 3
Long-Run Relationships

	Canada		France		Japan		U.S.		U.K.	
Variable	Coefficient	*t*-ratio	Coefficient	*t*-ratio	Coefficient	*t*-ratio	Coefficient	*t*-ratio	Coefficient	*t*-ratio
α_0	12.79	20.45	20.71	83.24	21.55	35.82	16.05	32.12	13.79	54.68
α_1	1.26	19.19	1.16	21.07	0.90	15.19	1.08	26.77	1.28	29.42
α_2	5.13	2.58	18.10	9.11	−11.26	−5.77	18.51	5.67	10.45	12.94

Note: All estimated parameters are statistically significant at the 5% statistical level.

The more the insurance industry is efficient, the more it encourages financial and economic development by stimulating both long-term saving and the financial and bank sectors. Otherwise, these strong economic linkages can also be attributed to the fact that the insurance sector may be in competition with financial companies and banks, which are also developing several products like the life premiums. This real competitive pressure can induce a cointegration relationship and an error-correction mechanism between financial markets and the insurance industry. Furthermore, the similarities in these results for all of these developed countries may indicate that most of their insurance companies control their costs while taking into account the fluctuations and tendencies of financial variables and/or using the same control techniques.

Second, we applied the linear cointegration tests to check the cointegration relationship hypothesis between the NLIP, stock prices, and interest rates, and we present the results in Table 4. The null hypothesis of no-cointegration is rejected for all of the countries studied since the residual term ($\hat{z}_t$) is stationary. The stationarity of the linear combination between the NLIP, stock indexes, and interest rates indicates the existence of significant, long-run relationships and of an active mean reversion between these series; it also suggests the presence of significant linkages and co-movements between financial and insurance markets in the long term. Therefore, our variables are at least linearly cointegrated, and their short-term dynamics can be reproduced using an LECM. However, the results and implications of linear cointegration tests should be carefully analyzed, since this modeling may imply misspecification problems. Indeed, linear cointegration tests are based on a linear framework and thus limit the NLIP adjustment dynamic to be symmetrical, linear, and invariant. For instance, they are not sound enough to reproduce other kinds of relationships between the insurance industry and financial markets in which the adjustment may be discontinuous, nonlinear, and asymmetrical, with time-varying adjustment speed.

Furthermore, the simulations of Taylor and Sarno (2001) showed that these tests might not be powerful when nonlinear processes generate data. In order to check the hypothesis of a nonlinear error-correction mechanism for the NLIP and that of a nonlinear cointegration relationship between insurance and financial variables, we applied nonlinear cointegration tests, which are more sound and powerful than linear cointegration tests.

TABLE 4
Linear cointegration Tests

Countries	p	ADF[a]
Canada	1	−3.829
France	1	−4.082
Japan	0	−3.238
U.K.	0	−3.40
U.S.	0	−6.331

[a]McKinnon critical value for augmented Dickey–Fuller test at the 5% statistical level is –3.34. The model retained for all countries is (a), the model with neither trend nor constant.

Nonlinear Adjustment Tests

This is an important and indispensable step that requires ESTECM modeling. According to Van Dijk and Franses (2000) and Van Dijk et al. (2002), the study of the nonlinear adjustment hypothesis in the long term can be carried out by following two steps. First, as we have previously done, we check the presence of a long-run relationship, while applying linear cointegration tests to verify the stationarity of the long-term relationship residual ($\hat{z}_t$). Second, we apply the nonlinear cointegration tests while testing the linearity of ($\hat{z}_t$) in order to check whether the adjustment is linear or nonlinear. More particularly, in our article, the nonlinear adjustment tests should check and detect the asymmetry and nonlinearity characterizing the NLIP adjustment dynamics toward equilibrium, which is defined by stock prices and interest rates. Of course, these second tests are more powerful and robust than linear cointegration tests. Rejecting the null hypothesis of linearity for the NILP deviations after accepting a long-run relationship between financial and insurance markets suggests that the NLIP is nonlinearly cointegrated with financial variables and that its dynamics are nonlinearly mean reverting toward equilibrium with a time-varying adjustment speed.

Before applying these nonlinear adjustment tests, the descriptive statistics of the NLIP deviations ($\hat{z}_t$) were computed and some preliminary tests were applied in order to specify *a priori* the nature of the dynamics of ($\hat{z}_t$), while examining the irregularities and the normality hypothesis in the insurance data. The empirical results are presented in Table 5. This preliminary analysis can help to determine *a priori* the statistical properties of the process generating the relationship between the NLIP and financial variables. If the process is linear, the Jarque-Bera test (J-B) should support the normality hypothesis and the distribution should be symmetrical (skewness = 0) with flat distribution tails (kurtosis = 3).[13] In practice, our results showed that the residual term series are asymmetrical for all studied countries since the skewness coefficient is statistically and significantly different from zero. It is negative for France and Japan, which may be a sign of nonlinearity characterizing the insurance dynamic series of these countries. Furthermore, even if the kurtosis values approach 3 and are sometimes only relatively different from 3, this can suggest that the distribution of the residual term does not necessarily have flat distribution tails

[13]The skewness test checks the hypothesis of symmetry against the alternative hypothesis of asymmetry and characterizes the degree of asymmetry of a distribution around its mean. A distribution is symmetric if it looks the same to the left and right of the center point. Positive (respectively, negative) skewness suggests a distribution with an asymmetric tail extending toward more positive (respectively, negative) values. The test of kurtosis measures the "fatness" of the tails of a distribution. It helps to measure the *peakedness* and tail *heaviness* of a distribution relative to those of a normal distribution. Positive excess kurtosis means that distribution has fatter tails than a normal distribution and indicates a leptokurtic distribution, whereas the distribution is, respectively, platykurtic for negative excess kurtosis and mesokurtic when kurtosis is equal to 3. In other words, leptokurtic characterizes a distribution that is simultaneously "peaked" and has "flat tails," while platykurtic characterizes a "less peaked" distribution, which has "thinner tails." The J-B test examines the hypothesis of normality and it is, more precisely, a goodness-of-fit measure from normality. It is based on skewness and kurtosis tests, and the asymptotic distribution of its statistics follows a chi-square with 2 degrees of freedom.

TABLE 5
Descriptive Statistics of $\hat{z}_t$

Countries	Standard Deviation	Skewness	Kurtosis	J-B
Canada	0.264	0.153	2.587	0.421
France	0.371	−0.461	3.089	1.647
Japan	0.271	−0.619	3.515	3.0
U.K.	0.284	0.992	3.821	7.88
U.S.	0.268	0.159	2.311	1.249

as those of a normal distribution. Finally, except the United Kingdom, the normality hypothesis is not rejected. However, we also have to carefully analyze the J-B conclusions since data are perhaps not long enough to validate these results.

Then, in a second step, following Van Dijk et al. (2002), we applied the nonlinear adjustment tests to the residual series ($\hat{z}_t$). These tests help to specify the NLIP adjustment dynamic while testing the null hypothesis of linear adjustment against its alternative of nonlinear adjustment of ESTECM type. Among the nonlinear tests, we used the Lagrange multiplier tests that have the advantage of having an identified distribution under the null hypothesis of linearity. We applied four tests: LM_1, LM_2, LM_3, and LM_4. Tests LM_1 and LM_3 are useful to test the linearity hypothesis against the LSTECM, whereas the LM_2 and LM_4 statistics test the linearity hypothesis against the ESTECM. However, in practice, LM_3 and LM_4 are the tests most frequently used and LM_3 is adequate enough to check the nonlinearity of both ESTECM and LSTECM types. For a complete presentation of these tests, see Van Dijk et al. (2002), Jawadi (2006), and Jawadi and Koubbaa (2007), among others. An example of the implementation of these tests was briefly described in Jawadi and Koubbaa (2007). Their application was done using a program written under WinRats 7.0.

In practice, these tests are based on the LECM specification. They require the determination of the lag number of the linear model (p) to apply these tests for several transition variables. In order to determinate the lag number, using also a program under professional Winrats 7.0, we mobilized the information criteria (Akaike (AIC), Akaike with second-order correction for sample sizes (AICC), and Schwarz), the autocorrelation functions, Bruesch and Pagan Lagrange multiplier test, and Ljung–Box (1978) tests. Our tests and computing retained $p = 1$ for Canada, Japan, the United Kingdom, and the United States, and $p = 2$ for France. These optimal values are chosen so that they minimize the information criteria for which the residuals are not autocorrelated. According to Teräsvirta (1994), the under- or overvaluation of the lag number (p) may bias the linearity tests.

Then, the nonlinear adjustment tests were applied to the lagged residual sets (z_t) and z_{t-d} is the transition variable. Since our data are annual, each nonlinear adjustment test was applied to four possible values of the delay parameter ($d = 1, 2, 3, 4$) and then to four possible transition variables. According to Teräsvirta (1994), the optimal transition variable is that for which linearity is the most strongly rejected. The empirical results of these tests are presented in Table 6. Our results showed that the linearity is not rejected for Canada and the United Kingdom since the p-values of all nonlinear adjustment tests are greater than 5 percent. However, the

TABLE 6
Nonlinear Adjustment Tests

d	Tests	Canada	France	Japan	U.K.	U.S.
$d = 1$	LM_1	0.603	0.250	0.570	0.289	0.581
	LM_2	0.941	0.612	0.244	0.542	0.516
	LM_3	0.946	0.518	0.173	0.396	0.204
	LM_4	0.983	0.662	0.698	0.784	0.398
$d = 2$	LM_1	0.826	0.248	0.153	0.26	0.198
	LM_2	0.906	0.122	0.441	0.86	0.179
	LM_3	0.986	0.068	0.052	0.760	0.10
	LM_4	0.998	0.082	0.091	0.342	0.093
$d = 3$	LM_1	0.999	0.629	0.259	0.739	0.232
	LM_2	0.999	0.896	0.674	0.404	0.443
	LM_3	0.999	0.462	0.785	0.355	0.193
	LM_4	0.999	0.532	0.651	0.479	0.281
$d = 4$	LM_1	0.619	0.447	0.227	0.644	0.433
	LM_2	0.948	0.816	0.363	0.279	0.596
	LM_3	0.997	0.834	0.194	0.366	0.805
	LM_4	0.987	0.495	0.80	0.273	0.891

nonlinear adjustment hypothesis is accepted for France, Japan, and the United States at the 10 percent statistical level for the same transition variable z_{t-2}. Yet, with more observations, perhaps the rejection of linearity could be more strongly suggested. Therefore, for these three countries, the NLIP adjustment dynamics are rather nonlinear, and our results suggest a certain degree of nonlinear dependence between insurance and financial variables. Furthermore, the results *a priori* suggest the presence of different regimes in NLIP dynamics that are activated depending on the intensity of their relationship with financial markets. Finally, the dispersion between the studied countries may imply that these countries do not identically take into account the degree of dynamism of their financial markets and its possible feedback on the insurance industry.

Overall, this result is interesting for at least two reasons. On the one hand, it highlights strong significant linkages between the insurance industry and the financial markets in the short and long terms, confirming the results of most previous studies that are discussed in the second section. On the other hand, the originality offered by the introduction of nonlinearity is that it defines different insurance premium regimes, indicating that some insurance premium variations are rather under the insurer's control whereas other variations are linked to regulatory and financial market structures. More importantly, the activation of the first "pure insurer" regime or of the second "regulatory and financial sectors" regime depends on the degree of trust in the insurance industry, the activity of insurance companies, and the financial market feedback exercised on the insurance industry. However, since it is usually quite hard to identify these two extreme regimes, we propose a modeling process (ESTECM) that not only captures these two extreme regimes but also is a continuum of intermediate states between these regimes. Moreover, another advantage of this modeling is to enable the transition between these NLIP regimes to be smooth rather than abrupt, thus reflecting the heterogeneity of insurers' expectations and policies. When facing a shock, insurers should instantaneously react but they cannot always respond simultaneously.

This kind of insurance relationship and dynamics for France, Japan, and the United States may escape the linear modeling techniques. In order to reproduce the NLIP adjustment dynamics for these countries, it would be better to retain a nonlinear framework.

Nonlinear NLIP Adjustment

In order to specify, within a nonlinear framework, the NLIP adjustment dynamics toward equilibrium of financial variables for France, Japan, and the United States, we applied the ESTECM methodology. In particular, we estimated an ESTECM (1, 2) for Japan and the United States, and an ESTECM (2, 2) for France. As we suggested before, the choice of the ESTEC representation can be justified differently and NLIP dynamics are *a priori* rather smooth, asymmetrical, and nonlinear for many reasons. First, when a shock affects, for example, financial markets, insurers can instantaneously react but they will not necessarily respond simultaneously, thus inducing some inertia effects and some persistence in the premium dynamics, which may imply a slow, rather than abrupt, NLIP dynamic. Second, the insurers' behaviors are not necessarily homogeneous. Insurers can have heterogeneous expectations and different investment horizons. They may assume distinct costs and have different extrapolative ratings. They may also control their costs differently and define their prices distinctly. Third, insurance companies may compete with each other and those having the lowest productivity are then under pressure. Indeed, the insurance industry may be characterized either by a small number of companies controling the most important part of the market, or by dominating state-owned, public companies that control the largest part of market premiums. Giving this insurance market structure, it seems obvious to suppose that the NLIP adjustment may be rather smooth, discontinuous, asymmetrical, and nonlinear. It can also be characterized by a time-varying convergence speed that varies according to the disequilibrium size due, among other things, to the feedback exercised by the heterogeneity of the insurers' expectations and costs, as well as by the interaction between financial and insurance markets.

In a first step, under the linearity hypothesis, we empirically estimated an LECM for France, Japan, and the United States, and we report the results in Table 7. Our results show significant relationships between current and past tendencies of the NLIP, rejecting the informational efficiency hypothesis for the three insurance industries. Moreover, our results checked evidence of significant linkages between insurance premiums and financial variables, particularly for France and Japan. Indeed, only French insurance premiums are significantly affected by the current variations of interest rates, whereas stock market deviations are statistically significant for Japan only. The dispersion between countries concerning the linkages with interest rates or stock prices might be due to the composition of the insurer portfolio. This is sometimes also limited by the insurance legislation and the insurers' habits. For example, in France, insurers invest a lot more in risk-free assets such as Treasury bills, which explains the significant linkage between interest rates and NLIP in the French case.

TABLE 7
LECM Estimation Results

	France		Japan		United States	
Variable	Coefficients	t-ratio	Coefficients	t-ratio	Coefficients	t-ratio
Constant	0.016	1.69**	0.042	2.46*	0.019	1.86**
ΔY_{t-1}	0.541	3.83*	0.338	2.4*	0.744	6.41*
ΔY_{t-2}	0.276	1.94**	–	–	–	–
ΔX_{2t}	0.979	2.54*	–	–	–	–
ΔX_{1t}	–	–	0.185	2.97*	–	–
z_{t-1}	−0.031	−2.43*	−0.043	−0.82	−0.045	−2.64*
$\overline{R}^2$	0.70	–	0.33	–	0.44	–
DW	2.06	–	2.09	–	1.76	–

* and ** designate significance, at the 5% and 10% levels, respectively.

Nevertheless, for Japan, the legislation compels insurers to invest a lot more in the asset price; this also explains the significant relationship between the stock and insurance markets for Japan. Moreover, these results are in line with those of most studies described in the second section.

More importantly, the linear adjustment term is negative and significant at the 5 percent level for France and the United States, indicating the presence of mean reversion between insurance premiums and financial variables and validating a linear cointegration mechanism for France and the United States. This result also implies possible significant linkages between the NLIP and financial variables, indicating that insurers take into account the variations of interest rates and stock prices while defining their policies, calculations, reasoning, and prices. The linear adjustment term is not statistically significant for Japan.

However, the LECM modeling limits the NLIP adjustment to be symmetrical, linear, continuous, and invariant. The extension of this modeling to a more general framework would be interesting to reproduce the possible cyclical movements characterizing NLIP dynamics. This idea, together with the estimation of the NLIP by the ESTECM, is at the heart of the following section.

ESTECM Estimation

The main aim of this empirical modeling is to explain the NLIP dynamics in a nonlinear framework. It also attempts to explain its possible linkages with financial markets and to specify its different consequent regimes according to the intensity of the feedback exercised by financial variables and insurers' behaviors on the NLIP. In such a context, the ESTECM were estimated by the NLS method. This requires different executions of a nonlinear algorithm and the experimentation of several initial values for the ESTECM parameters.[14] More precisely, we first estimated the LECM by the OLS method and we retained its estimators to initialize the AR parameters of the ESTECM. Second, we initialized γ and c according to Teräsvirta (1994) and then we

[14]The estimation was also carried out using a software program written under Professional Winrats (7.0).

TABLE 8
ESTECM Estimation Results

	France ESTECM (2, 2)		Japan ESTECM (1, 2)		USA ESTECM (1, 2)	
	Coefficients	t-ratio	Coefficients	t-ratio	Coefficients	t-ratio
θ_0	0.007	0.81	0.038	2.38*	0.023	2.34*
ρ_1	0.037	1.35	0.911	1.73**	0.542	1.44
$\theta_{1,1}$	0.542	4.04*	0.526	3.68*	0.672	5.96*
$\theta_{1,2}$	0.299	2.22*	–	–	–	–
$\theta_{2,0}$	–	–	0.183	3.11*	–	–
$\theta_{3,0}$	0.914	2.54*	–	–	–	–
ρ_2	−0.104	−3.06*	−1.019	−2.02*	−0.592	−2.58*
γ	1.37	2.05*	6.96	2.21*	51.8	2.47*
c	0.502	5.92*	−0.172	−9.94*	0.03	1.83**
$\frac{\sigma_{NL}}{\sigma_L}$	0.78	–	0.66	–	0.82	–
N	20	–	23	–	41	–

* and ** designate significance at the 5% and 10% levels, respectively. $\frac{\sigma_{NL}}{\sigma_L}$ is the ratio of residual variances of the ESTECM and the LECM, and N indicates the number of convergence iterations.

estimated and reestimated the ESTECM by the NLS method until the estimators of the ESTECM did not vary any more.[15] The estimation results of the ESTECM are reported in Table 8.[16]

Our results suggest several interesting empirical features concerning the NLIP adjustment dynamics. First, they show two types of regimes for the NLIP adjustment dynamics, depending on the degree of linkage between the insurance industry and financial markets. Their realization and activation depend on the signs and values of the nonlinear adjustment terms (ρ_1 and ρ_2). Furthermore, the switching between these regimes can be economically explained in function of the intensity of the feedback exercised by financial markets on the insurers' behavior and reaction. Second, our results indicate strong evidence of nonlinear mean reversion of the NLIP toward financial variables, given the significant estimators of the transition function and those of the adjustment terms for the three countries. They reveal a nonlinear error-correction mechanism between insurance and financial markets for which the convergence speed is rather time varying. More precisely, as in Michael et al. (1997), we highlight nonlinear behavior for the NLIP that can

[15]The retained convergence criterion is 0.00001.

[16]The equation presenting the ESTECM is repeated below

$$\Delta Y_t = \theta_0 + \rho_1 \hat{z}_{t-1} + \rho_2 \hat{z}_{t-1} \times F(z_{t-d}, \gamma, c) + \sum_{i=1}^{p} \theta_{1,i} \Delta Y_{t-i} + \sum_{j=0}^{p} \theta_{2,j} \Delta X_{1,t-j} + \sum_{l=0}^{p} \theta_{3,l} \Delta X_{2,t-l} + \varepsilon_t,$$

where Y_t is the NLIP in logarithm; $X_{1,t-j}$ is the lagged stock price in logarithm; $X_{2,t-1}$ designates the lagged interest rate; z_{t-1} is the error-correction term; z_{t-d} is the transition variable; $F(.)$ is the transition function; γ and c are, respectively, the transition speed and the threshold parameters; ρ_1 and ρ_2 are, respectively, the adjustment terms in the first and the second regimes; $\theta_{1,i}$, $\theta_{2,j}$, and $\theta_{3,l}$ are the AR parameters; and ε_t is distributed as i.i.d.

be well reproduced by the threshold cointegration model of the ESTECM type.[17] This modeling explains the time-varying interaction and the adjustment of the insurance industry toward financial variables, particularly due to the introduction of a component of nonlinear transition function and of two adjustment terms in the model.

More significantly, this nonlinear NLIP time-varying mean reversion is governed by the signs and values of the major parameters of the ESTECM (ρ_1 and ρ_2), which are statistically and economically significant (notably ρ_2, the most important parameter). Indeed, the estimation of these parameters suggested, in particular, that the more important the NLIP disequilibrium, the stronger the NLIP mean reversion toward the long-run equilibrium defined by the financial variables. To be more precise, the relations or conditions should be respected to validate a nonlinear cointegration process and a threshold mean reversion in the NLIP, which is the case in France, Japan, and the United States. In other words, the NLIP dynamics can be characterized by a unit root or an exploding behavior (in the first regime corresponding to the central regime of the exponential function) for small deviations toward equilibrium, but for large NLIP deviations, the NLIP adjustment process should be nonlinearly mean reverting toward equilibrium. Moreover, the larger the NLIP, the higher the convergence speed.[18]

Empirically, the adjustment term of the first regime (ρ_1) is positive for the three countries and significant at 10 percent only for Japan. This implies that in the first regime, the NLIP can deviate from equilibrium and premiums may be characterized by an exploding behavior in this regime. Insurers may very well propose some exceptional promotions or rates in order to be more competitive. However, when these deviations exceed a certain threshold defined by insurers' costs and financial variables, the NLIP should return to the long-run equilibrium and incorporate the financial variable variations. Nevertheless, using macroeconomic data, this mean reversion may appear to be rather smooth, since insurance companies do not necessarily assume the same costs and do not have the same policies. Indeed, each one has its own specific cost and specific threshold; therefore, the adjustment is active only when it implies some opportunities for all insurers.

The adjustment term in the second regime (ρ_2) is negative and statistically significant at 5 percent for the three countries. As the sum of the two adjustment terms ($\rho_1 + \rho_2$) is also negative, it indicates that the NLIP is nonlinearly mean reverting toward equilibrium, implying an asymmetrical and nonlinear cointegration process for the American, French, and Japanese NLIP. These results are interesting and important, in particular because they highlight different regimes for the NLIP and the insurers' behaviors that are activated per period according to the financial and economic conjuncture state. The transition speed between these regimes is relatively low, suggesting the smooth and slow character of the premium dynamics and confirming our economic discussion concerning macroeconomic insurance data. The transition is a little abrupt for the United States. γ is statistically significant at 5 percent for the three countries and the threshold (c) is also significant as it confirms the choice of the

[17]The study of Michael et al. (1997) concerned exchange rate deviations.

[18]The advantage of the exponential transition function is to reproduce the NLIP adjustment speed in function of the size of the NLIP deviations.

ESTECM and indicates that the exponential function is appropriate to the replication of the NLIP adjustment dynamics toward financial markets. It is also adequate to reproduce the cyclical movements characterizing insurance industries (Figure A1 in Appendix A) and the phases of NLIP toward financial variables.

In order to explore the properties of the transition between the NLIP regimes, we presented the graphics of the transition function in Figure B1 in Appendix B. More precisely, we plotted the estimated transition on the vertical axis and the transition variable on the horizontal axis. Our analysis suggests several interesting findings. First, the hypothesis of a time-varying NLIP speed is checked for the three countries, since the more the deviation increases, the more elevated the transition function and the stronger the mean reversion. Second, for both the United States and Japan, we clearly identified the central regime corresponding to the "purely insurer" for which the NLIP can deviate from the equilibrium and last away from it, and we identified the outer regimes assimilated to the regime of "regulatory and financial sectors" in which the NLIP is defined and dominated by financial variables. However, in the French case, the dynamic approaches a logistic rather than exponential function and two regimes are identified: a low regime and a high regime.[19] More importantly, except for the United States, the estimated transition function rarely approaches unity, confirming the slowness of the adjustment and transition between the insurance regimes. For the United States, the important value of the transition function can be associated with the strong linkage between insurance and financial markets and with the excessive activity and feedback exercised by the latter on the American insurance industry.

Concerning the other explanatory variables, our results also suggest that changes in current premiums are significantly and positively related to changes in 1-year lagged premiums in Japan and the United States, while in France, changes in current premiums are significantly and positively related to changes in 1- and 2-year lagged premiums. Concerning the influence of interest rates, the short-term changes in premiums are not directly related to those in interest rates for the United States and Japan. This result is similar to the result of Grace and Hotchkiss (1995), who found a long-term relationship between the American combined ratio and interest rate, but no significant relationship between these variables in the short term. However, changes in premiums are positively related to changes in interest rates for France. This result is also similar to that of Blondeau (2001), who suggested a significant relationship between the French premium and interest rate in the short and long terms. For Japan, as in the LECM, stock price current deviations significantly and positively affect its NLIP.

Finally, the ratio of residual variances show an interesting result. It is significantly lower than 1 in the three cases, indicating that the introduction of nonlinear components reduced the NLIP residual variance and also showed the superiority of the ESTECM compared to the LECM in reproducing the NLIP cyclical movements. This implies a strongly nonlinear adjustment NLIP for the three countries. This is also suggested by the misspecification tests, which showed that the residuals of the three estimated adjustment models have good statistical properties.

[19] Examining the dynamic of the French NLIP using other transition functions can be the subject of further research.

Overall, the main findings and contributions of this study are as follows. (1) There are at least two different regimes that characterize the NLIP dynamics: the "purely insurer" regime and "regulatory and financial sectors" regime. The activation of the first regime depends on the degree of trust in the insurance industry, whereas the second is associated to the intensity of the financial market feedback exercised on the insurance industry. (2) The NLIP adjustment dynamic toward equilibrium is rather asymmetrical, smooth, and nonlinear, with a time-varying adjustment speed that increases with the NLIP deviation size. This smoothness and persistence are induced by the heterogeneity of the insurers' expectations and costs, the degree of competition between insurers, the coexistence of different degrees of risk aversion, the different investment horizons, the information asymmetry, and the linkages and interaction between financial and insurance markets. (3) Insurers continually revise their reasoning and reactions and adjust their prices on the basis of financial variable deviations. Formally, this means that although the NLIP and financial variables may undergo some short-term disruptions, they have similar properties in the long term and they may establish steady relations with one another that nonlinearly converge toward the long-run equilibrium.

CONCLUSION

The main objective of this article is to study the NLIP in a nonlinear framework and to examine its relationships with financial markets in five developed countries. First, a brief empirical literature review highlighted strong evidence of heterogeneous results concerning the linkages between the insurance industry and the financial markets. This distortion in the preceding empirical results may be associated with misspecification problems while modeling the insurance premium dynamics. Most previous studies retained the linear framework to explain the insurance premium adjustment. While extending the study of this topic to the nonlinear framework, we found significant relationships between insurance and financial markets. More particularly, we noted that the use of the cointegration framework helps to specify these linkages in the short and long terms and to define an error-correction mechanism for the NLIP toward equilibrium that is induced by financial variables (i.e., interest rates and stock prices).

Concerning the NLIP adjustment, the application of nonlinear cointegration and the estimation of a threshold error-correction model showed a nonlinear NLIP error-correcting mechanism for France, Japan, and the United States. We highlighted a significant asymmetrical and nonlinear cointegration relationship between the NLIP, interest rates, and stock prices whose convergence speed, as it is suggested by the estimated transition function, is time varying and increasing in function of the NLIP deviation size. The estimation of an ESTECM for the above countries suggested that the NLIP dynamics is characterized by two regimes: a first, "purely insurer" regime, and a second one governed by the "regulatory and financial sectors."

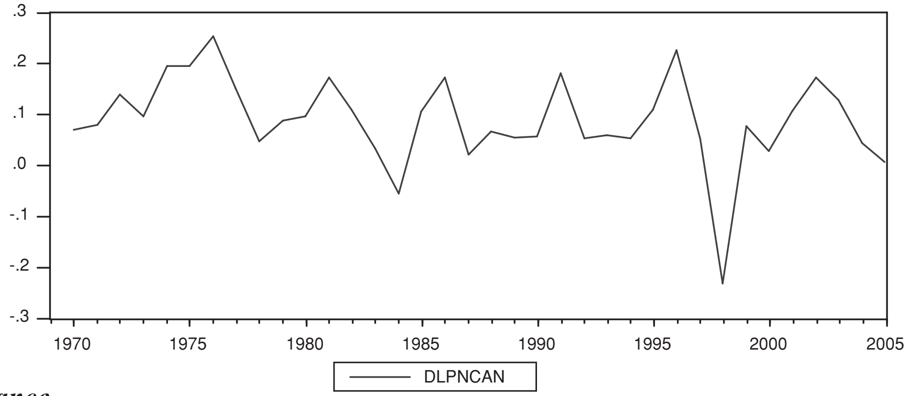
One of the shortcomings of this study is the lack of data on claims. Perhaps, it would be promising and interesting to include variables such as losses and reinsurance prices, as they surely play a role in determining NLIP dynamics. As far as further research is concerned, it would be interesting to use by-line premiums instead of aggregate premiums because the underwriting cycle of premiums varies across the line.

APPENDIX A

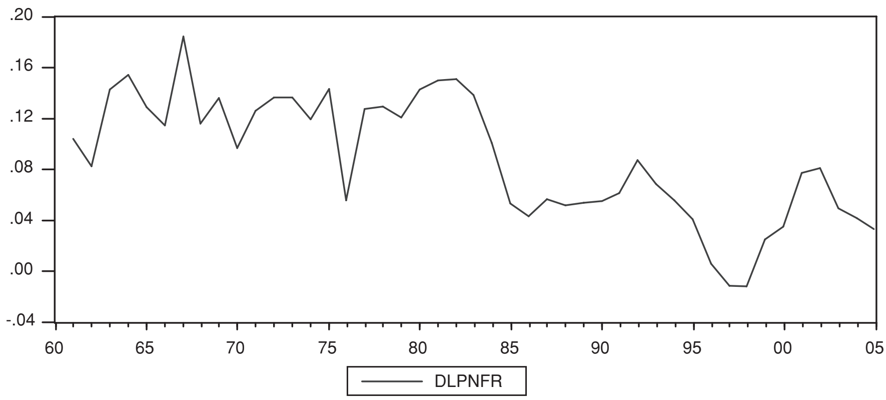
FIGURE A1

The NLIP Growth Rate

Canada



France



Japan

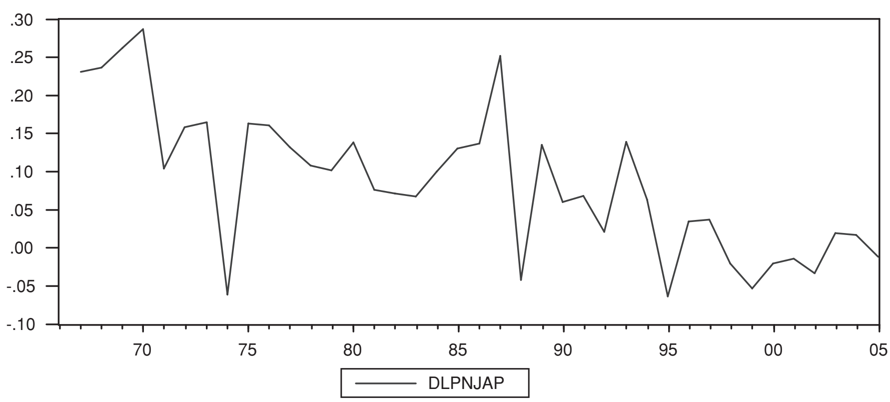
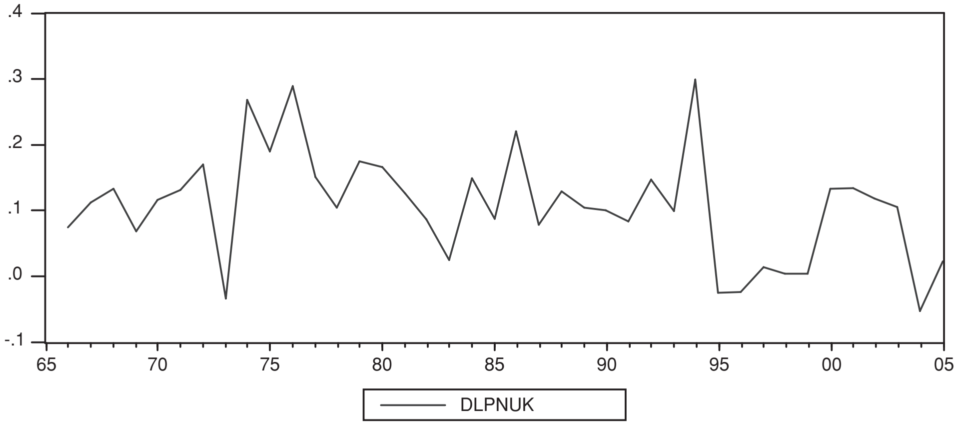
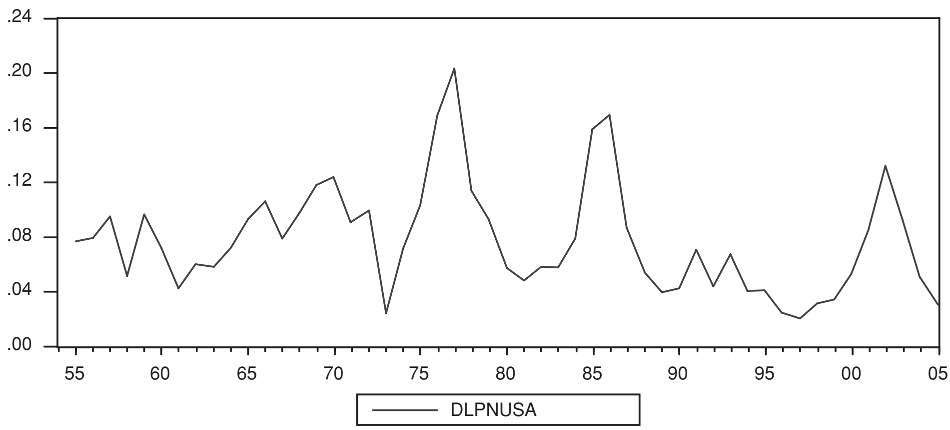


FIGURE A1
(Continued)

United Kingdom



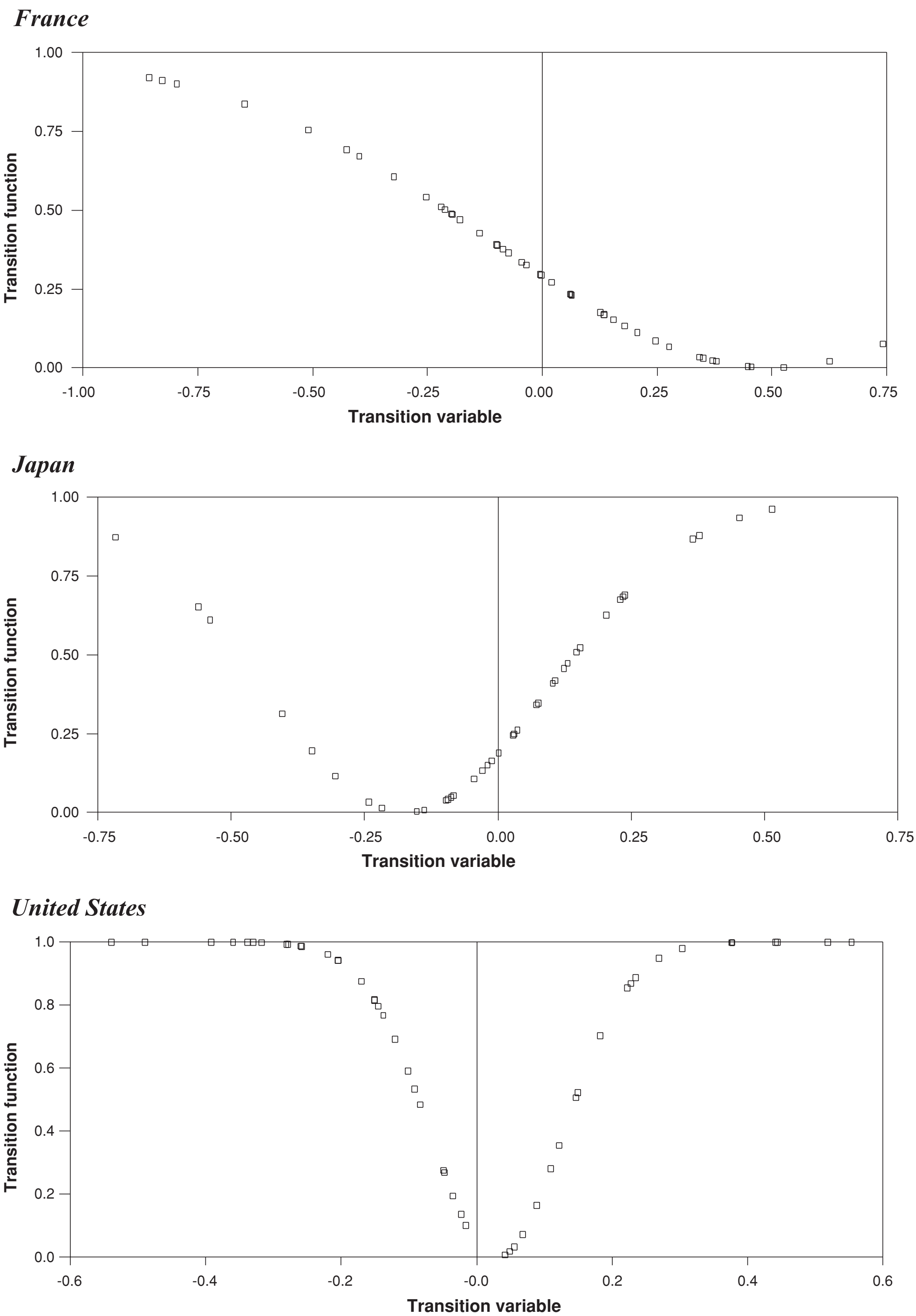
United States



APPENDIX B

FIGURE B1

The Estimated Transition Functions



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