Why Has Swedish Stock Market Volatility Increased?

by

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Preliminary

Abstract

Is the increased volatility on the Swedish stock market due to increased sensitivity to foreign markets or to inherently Swedish factors? The findings in this paper is that the foreign influence on the Swedish stock market shows a clear positive trend while purely domestic factors have not become more volatile. World influence on domestic stock markets is also substantially larger during international high volatility periods than during calmer periods on the world market. Furthermore, when the volatility of the world stock market shifts to its higher level, both the world and the domestic markets simultaneously fall quite dramatically.

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1. Introduction

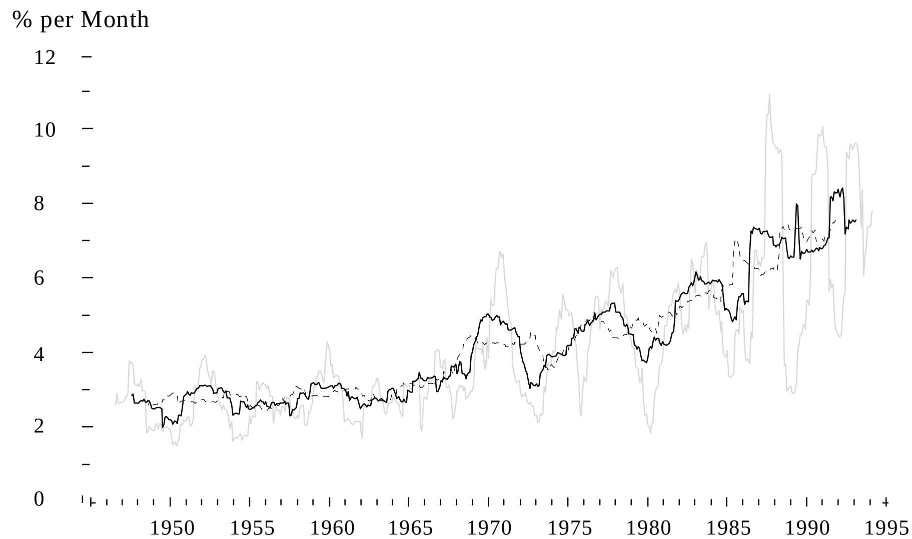
Events on financial markets have come to play an increasingly important role in media and public discussion. All big news media today have daily coverage of the latest developments at the stock markets. Sudden shifts in the value of the stock market and periods of higher than usual financial volatility get a lot of attention. The tight media coverage is an indication that it is perceived, at least by journalists, that a lot of valuable information can be derived from the developments at the stock market. The stock market has the convenient feature that it is easily observable and reacts vigorously and with short lags to news.

Although little formal work has been done in this area, it is often suggested that shifts in financial volatility can be of importance for macroeconomic performance. Christina Romer (1990), for example, argues that increased uncertainty associated with financial distress was one of the driving forces behind the great depression. Also the very sharp recessions in Sweden and Finland in the beginning of the 90's, in many respects comparable in size to the depression in the 30's, is often attributed to increased savings caused by a shift in uncertainty even though the connection to the stock market may be less clear here.

It is now a well-established fact that financial volatility is a non-constant stochastic process with a non-negligible degree of persistence – if stock market volatility is high today it tends to be high also during the nearest future. This observation has received much attention from the finance profession due to its implications for asset pricing and portfolio management. The changing volatility and in particular its persistence, however, also has potential macroeconomic implications.

To understand the implications of time varying financial volatility, more knowledge of the processes that drive volatility is required. In particular, I am in this paper interested in intra-market dependence of national stock markets. If a high or increasing volatility on the Swedish stock markets can be attributed to a purely domestic news source, this may have different implications, both for policy and consumption/investment decisions than if the volatility comes from a strong sensitivity to world market developments. Here only a few studies have been conducted. Engle and Susmel (1993) and King et al (1994) estimate multivariate models with common factors. An often noted observation is that there appear to be regime shifts in the covariance matrix of different national stock markets (see Bollerslev, 1992, p. 30). During periods of high volatility there appears to be a tendency of higher international dependence.

Figure 1 Moving Standard Deviations of Nominal Returns on the Swedish Stock Market



Source: Updated data from Frennberg and Hansson (1992).

In *Figure* 1 I show a graph over the standard deviation of the return on the Swedish stock market. The gray line represents the standard deviation during the period starting 6 months before and ending 6 months after the observation date, i.e., it covers one centered year around the observation date. The solid black line represents the standard deviation for the centered 3 year period and the dashed the 5 year period. In the graph we may observe that also the Swedish market has periods of higher volatility. More striking is the strong trend in volatility. From hovering between 2 and 3 % a month the volatility started increasing sometime during the 60s to reach levels more than twice as high in the 90s.[1] Such a trend cannot be found on the aggregate world stock market or in US, for example.

The purpose of this paper is to examine to what extent this trend is due to purely domestic factors or to an increased sensitivity to the world market. Furthermore, I want to

[1] In the formal analysis below I will control for variations in inflation by studying stock market return in excess of a safe interest rate.

evaluate the effects on the Swedish stock market when the world market goes into a spell of higher than typical volatility. Here I am interested both in level shifts and changes in the degree of comovements. Lastly, I want to compare the results with a few other relatively small European stock markets.

We will se that there is strong evidence suggesting an increased international sensitivity as the main reason for the increased volatility on the Swedish stock market. Domestic factors seem to play only a minor role for the increase. We will also see that there is distinct states that determine the volatility on the world stock market. When a volatility period is entered, both the world and the Swedish market take large falls – in the order of 5 to 9%. After that, the world influence on the domestic markets are substantially larger than during international calm periods.

We will also see that purely domestic news show systematic variations in volatility. The model distinguishes high volatility periods of approximately twice the volatility of the low volatility periods. Low volatility periods are on average longer than high volatility risk. In Sweden, a shift to the domestic high risk state is often followed by an shift back the following month. Given that this shift back do not occur – the domestic high risk state is fairly persistent with an expected length of over 7 months. For the other domestic markets we find similar results.

In section 2 I present the econometric model. Diagnostic testing of models with switching volatility is somewhat intricate and a standard procedure has yet to develop. I thus devote Section 3 to a discussion of diagnostic tests, test results and implications for re-specification. Such test are required since they are the only way of evaluating how well the model describes data. The estimation results are then presented in section 4 and section 5 concludes.

2. Model

2.1 The World Market

Suppose that there exists a stochastic news process denoted ε^w that drives the world stock market. Suppose further that there exists a stochastic state variable, denoted s_t^w that determine the volatility of this news process. Assume that this risk state only can take two values, 0 and 1, although extension to any finite number of states is straight forward in principle. When the world risk state is 0, the standard deviation of the news process is ω_1 and when it is 1 the standard deviation is $\omega_1+\omega_2$. We can think of the risk state as indicating "stable" or "unstable" weather. Furthermore, assume that the world risk state follows a first order stationary Markov chain with the probability of staying in each state given by $q^w(s_t^w)$.

The expected return on the world stock market is likely to be different in the two risk states. Furthermore, if a shift in the risk state occurs between time *t* and *t*-1, it is likely that the realized return is affected. If, for example, the world market may fall if it goes into the high risk but then have higher expected returns as long as the high risk state prevails. We may then model the excess return, i.e, realized return minus a safe interest rate as follows;[2]

$$r_{t+1}^w - r_{t+1} = \mu_1 + \mu_2 s_t^w + \mu_3 \Delta s_{t+1}^w + (\omega_1 + \omega_2 s_{t+1}^w)\varepsilon_{t+1}^w. \tag{2.1}$$

where r_{t+1}^w is the realized return on the world stock market, r_{t+1} is the safe interest rate, μ_1 is the expected return in risk state 0 if no state shifts occur, μ_2 is additional expected return in state 1. The shift in the level of the stock market at state shifts is given by μ_3. The news, ε^w, is an i.i.d. standard normal so the standard deviation of the last term is ω_1, and $\omega_1+\omega_2$ in the two states respectively.

Now turn to the domestic stock market. The return on the domestic market is assumed to be driven by both the world news to dividends and by an idiosyncratic domestic news process denoted ε^d. The influence of the foreign news process is allowed to shift with the international risk state. Also the intensity of the domestic news process is allowed to shift as a domestic risk state, denoted s_t^d shifts. The domestic risk state can also take the values 0 and 1 and follows a

[2] A formal derivation of based on a standard asset pricing model is presented in the appendix.

Markov chain with continuation probabilities $q^d(s_t^d)$, so it is assumed to be independent of, in particular, the world risk state.

Expected returns on the domestic market depends on both the domestic and the world state. Realized return will also be affected by domestic and world risk state shifts. As noted in the introduction, there is evidence of a trend increase in the volatility on at least the Swedish stock market. To model such a trend in the simplest possible way, I allow a deterministic time trend in the volatility of the innovations to the domestic dividend process as well as to the drift terms and their sensitivity to the risk states.[3] The final bivariate model is then given by

$$\begin{aligned} r_{t+1}^w - r_{t+1} &= \mu_1 + \mu_2 s_t^w + \mu_3 \Delta s_{t+1}^w + (\omega_1 + \omega_2 s_{t+1}^w)\varepsilon_{t+1}^w, \\ r_{t+1}^d - \bar{r}_{t+1}^d &= \mu_4 + \mu_5 s_t^w + \mu_6 \Delta s_{t+1}^w + \mu_7 t/T + \mu_8 s_t^w t/T + \\ &\quad \mu_9 s_t^d + \mu_{10} \Delta s_{t+1}^d + \mu_{11} s_t^d t/T \\ &\quad + (\omega_3 + \omega_4 s_{t+1}^w + \omega_5 t/T)\varepsilon_{t+1}^w + (\omega_6 + \omega_7 s_{t+1}^d + \omega_8 t/T)\varepsilon_{t+1}^d \end{aligned} \tag{2.2}$$

where T is the total number of observations.

If the market structure changes so that, for example, capital controls are lifted we expect to find non-zero estimates of μ_7, μ_8 and/or μ_{11}. This since these changes affect how the different sources of risk are priced. The sensitivity to the domestic state, for example, should plausibly fall as domestic volatility is idiosyncratic from the point of view of an investor with access to the world market. This will change the covariance between domestic and foreign returns also if the news processes are invariant over time. If, on the other hand, the domestic influence of foreign news increases or if the strength of the domestic news flow changes, ω_6 and/or ω_9 should be positive.

2.2 Data and estimation

Stock market yields are calculated from the Morgan Stanley Capital International (MSCI) indices, which include re-invested dividends. The sample period is 1970:1-1995:8. The returns are calculated as the log-difference of month-end stock market index calculated in US dollar terms. Yields thus include an exchange rate term. Ideally we may want to model

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[3] Certainly, such trends cannot be infinitely lived. There is no presumption, however, that the estimated model is going to describe data well that long. What we can hope for is a model that does a good job as a *local approximation* to the true data generating process.

exchange rate fluctuations as a separate stochastic process. This is not done in this paper. The risk-free interest rate is the 30-days Eurodollar rate, provided by the Swedish Central Bank. The world market return is calculated from the MSCI value-weighted world index.

The model is estimated in the recursive way devised by Hamilton (1989). Employing this recursive method makes it very easy to change the specification of the model. It is, in particular, easy to include time varying parameters. Standard errors are calculated from the Hessian of the loglikelihood function at the estimated parameters. Instead of estimating the transition probabilities directly, I estimate them as argument in the cumulative normal distribution function. The standard deviation of these parameters are calculated using the δ-method.

3. Diagnostic Tests

3.1 Model Diagnostics

Before examining the results of the estimation of the model, we want to judge whether the model can be thought of as a reasonable description of the data. For this purpose I will, in some detail, first present the results from some diagnostic tests, based on work by Hamilton (1996). One could certainly test the statistical model in many dimensions and it is a priori clear that the probability of this model being exactly right is zero. The tests should thus be thought of as quantitative evaluations of how well the model, in some dimensions, describe data. Based on the purpose of this paper and the suggestions by Hamilton (1996), I have chosen to evaluate the model along the following dimensions:

1) We want to judge whether the volatilities of the information processes are reasonably well described by the two-state model. This will be tested against the hypothesis that there remains some autocorrelation in the volatility, i.e., that some ARCH-effects remain.

2) We also want to see if there is strong evidence against states follow independent first order Markov processes. Alternatively they may have higher order, be inter-dependent and/or depend on the level of the realized return.

3) Lastly I want to check whether the average return is constant in the two states, after potential linear time trends have been removed. Alternatively, there may remain some autocorrelation in the return.

The test are based on an examination of the derivatives of the loglikelihood function – the scores. Define as the vector of scores at time t as

$$\mathbf{h}(t) \equiv \partial \ln f\left(\mathbf{r}_t \middle| \mathbf{r}_{t-1},\ldots,\mathbf{r}_1;\Phi\right) \Big/ \partial\Phi \tag{3.1}$$

where f is the log-likelihood function, $\mathbf{r}_t$ is the vector of excess returns at time t and Φ is the vector of parameters to estimate. If the model is correctly specified, each element of $\mathbf{h}(t)$, is uncorrelated with all information in t-1. In particular, it should be uncorrelated with previous values of the itself and other scores. Intuitively, if this is violated we expect that our parameter estimates will change in some known direction when a data point is added to our sample. This could never be a feature of a reasonable estimator. By looking at linear relations between scores in t and t-1 we may detect deviations from the assumptions in the model and may understand how they are violated. To this end I will study the following regressions

$$h_i(t) = \alpha_0 + \sum_{j \in J} \alpha_j h_j(t-1) + \varepsilon_t \tag{3.2}$$

where $h_i(t)$ is the ith element of the score and J is a subset of the parameters I estimate. If the model is a reasonable description of date, regression (3.2) should have insignificant explanatory power.

We should note that the residual in (3.2) in general is heteroschedastic, implying potentially serious small sample problems. These will be particularly severe for parameters that influence the likelihood function only at state realizations that occur with low probability. As we will soon see, the transition probabilities for both the domestic and the world state are low. This means that state switches are rare events. The scores for parameters that only affect the likelihood function at state switches, i.e., μ_3, μ_6, and μ_{10}, will thus follow very heteroschedastic processes and tests based (3.2) will be quite unreliable.[4] We can understand this in the following way; despite the relatively large nominal number of degrees of freedom, we have relatively little information about of what happens at state shifts since these events are rare. I will thus exclude the scores for theses parameters from the tests. I am in effect thus testing the model according how it behaves within the states, not what happens exactly at the state shifts.

To test the Markov assumption that the probability of state shifts only depend on the current state, I have performed two tests. The first, Markov I, is to run one regression for each of the scores with respect to the probabilities $q^w(0)$, $q^w(1)$, $q^d(0)$ $q^d(1)$. In this test, one period lagged values of the four scores are used as regressors. This test is aimed at detecting deviations from the independent first order Markov assumption. If lagged values of scores predict scores for the same state variable, this is an indication of violation of the first order assumption. Similarly, if lagged scores can predict the score of the other state variable, this indicates non-independence between the two state variables, e.g., that a state shift on the world market tends to be associated with state shifts in the purely domestic state variable.

In the second test, Markov II, the same dependent variables are used, but they are now regressed on the lagged scores for the drift parameters μ_1, μ_2, μ_4, μ_5, μ_7, μ_8, μ_9 and μ_{11}. This test can detect if the level of the stock return in the previous period contains information about the likelihood of staying in the state, which would violate the Markov assumption.

The third test, AR, is aimed at detecting deviations from the assumption of a constant expected return (except for the time trend) in each state. I run regressions for each of the scores for μ_1, μ_2, μ_4, μ_5, μ_7, μ_8, μ_9 and μ_{11} against the lagged scores for the same parameters. If there is some autocorrelation in the return processes left unaccounted for by the model, these regressions should contain some information.

The last test is an ARCH test. I run regressions for each of the scores with respect to the volatility parameters. ω_1,..., ω_8. Significance here indicates remaining ARCH effects. If, for example the lagged score with respect to ω_1 helps predict the current value of the score, there seems to be ARCH effects in state 1. Hamilton's (1996) propose the same four tests. The

[4] The scores for these parameters showed long periods of values close to zero interrupted by a small number of very large values.

difference is only that he tests whether all regressions within a test simultaneously have zero R^2. Studying the regressions separately can, however, give an indication of what causes a potential rejection and guide model re-specification.

I have chosen to use a critical level of 1% to reject the model. Hamilton's (1996) notes that in Monte Carlo simulations there is a tendency to reject to often. This is probably due to that many individual scores are far from being normal, with large outliers occurring with relatively long intervals as discussed above. Considering this and the large number of tests, 1% rejection level does not seem overly in favor of the model.

Table 1 Score tests

Country		Markov Test I				Markov Test II				AR Test							
		$q^w(0)$	$q^w(1)$	$q^d(0)$	$q^d(1)$	$q^w(0)$	$q^w(1)$	$q^d(0)$	$q^d(1)$	μ_1	μ_2	μ_4	μ_5	μ_7	μ_8	μ_9	μ_{11}
	$\bar{R}^2$	0.00	0.00	-0.01	0.09	-0.02	0.04	0.00	-0.01	0.00	0.02	-0.01	0.00	-0.01	0.00	0.00	0.01
Sweden	p-value	0.57	0.57	0.65	0.00	0.93	0.01	0.46	0.59	0.38	0.07	0.75	0.45	0.64	0.42	0.39	0.19
	$\bar{R}^2$	-0.01	0.00	-0.01	0.00	-0.02	0.02	0.00	-0.01	0.00	0.01	-0.01	-0.01	-0.01	-0.01	0.02	0.00
Belgium	p-value	0.72	0.54	0.98	0.31	0.98	0.07	0.31	0.66	0.50	0.28	0.88	0.85	0.87	0.73	0.08	0.34
	$\bar{R}^2$	0.00	0.00	0.01	0.00	0.01	0.00	0.00	-0.01	-0.01	-0.02	0.01	-0.01	0.00	-0.01	0.04	0.06
France	Prob	0.62	0.26	0.83	0.30	0.77	0.32	0.33	0.73	0.81	0.95	0.25	0.69	0.44	0.75	0.01	0.00

Country		ARCH Test							
		ω_1	ω_2	ω_3	ω_4	ω_5	ω_6	ω_7	ω_8
	$\bar{R}^2$	-0.02	-0.02	0.01	-0.01	0.01	-0.01	0.03	0.00
Sweden	Prob	0.99	0.92	0.23	0.85	0.22	0.66	0.11	0.43
	$\bar{R}^2$	-0.01	0.01	0.00	0.00	-0.01	-0.01	0.04	-0.01
Belgium	Prob	0.87	0.18	0.49	0.51	0.72	0.83	0.02	0.75
	$\bar{R}^2$	-0.02	-0.01	-0.01	-0.01	-0.02	-0.02	0.03	-0.02
France	Prob	0.98	0.60	0.84	0.82	0.96	0.97	0.03	0.93

In *Table* 1 I present the results of the score test for the bivariate model for excess returns on the Swedish and the world market. I report the centered R^2 together with the asymptotic p-value for $R^2=0$. The diagnostic test results are discussed in the following sections.

3.1.1 Diagnostic results for Sweden

In Table 1 we find evidence of violations of the Markov assumption. These are related to the scores with respect to the transition probabilities.

The assumption that the domestic state follow a first order, independent Markov chain is significantly rejected. In the regression of $q^d(1)$ in Markov test 1 we find a strong dependence on lagged scores with respect to the other transition probabilities. A closer inspection of the regression results indicates that the *t*-values in the regression are 0.03, -0.27, 5.79 and 2.77 for the scores for $q^w(0)$, $q^w(1)$, $q^d(0)$ $q^d(1)$.[5] This indicates that it is the first order assumption rather than the assumption of independence between the state variables, that is violated. I will thus re-estimate the model allowing the probability of staying in domestic state 1 to depend on the current as well as the lagged state. The probability of staying in domestic state 1 if the current and the previous state was 1 will be denoted by $q^d(1,1)$ and the probability of staying in state 1 if the previous state was 0 by $q^d(1,0)$.

There is also an indication that previous returns may influence the probability of staying in world state 1 – the second regression in Markov test II is significant. The significance is, however, due to the score with respect to μ_8. This would mean that the realization of Swedish returns affects the probability of the world process to stay in its high risk state – which seems unreasonable. A closer inspection of the regression also shows that the significance is due to only one single observation – September 1990. If this is excluded the significance of the regressions is reduced to a marginal p-value of 0.20. The Swedish stock market had its lowest rate of return over the who sample this month – -25%. Apparently this occurred one period before a realization on the world market that tended to push the estimate of $q^w(1)$ upwards. This seems to be a coincidence rather than a causal relationship. To handle this I include a dummy for the Swedish return in September 1990. I thus treat the return for this month as an outlier – unexplained within the model.

None of the regressions in the AR and the ARCH tests are significant at conventional levels. So there does not seem to be any significant AR or ARCH effect left in the data.

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[5] t-statistics for all regressions are presented in the Appendix.

After re-estimating the model allowing $q^d(1,1) \neq q^d(1,0)$ and using a dummy for the Swedish return in September 1990 the model survives the tests in the sense that no regressions are significant at conventional significance levels. The p-values of the regressions are given in *Table* 2. The new parameter estimates are very close to the estimates for the rejected model.

3.1.2 Diagnostic results for Belgium

From Table 1 we see that the model survives the tests. The only case where the test us close to reject is the ARCH test for ω_7 with a marginal level 1.7%. This turns out to be du to one single observation February 1986, when the Belgium stock market realized its largest return in the sample, amounting to 23%. Since the tests are not rejected I accept the base model. I have, however, re-estimated the model including a dummy for domestic return in February 1986. Then the marginal significance level of the see that this takes away the rejection of the ARCH test for ω_7 increases to 45%. The parameter estimates are very close in the two estimations.

Table 2 Score tests for Final Models

Country		Markov Test I				Markov Test II				AR Test							
		$q^w(0)$	$q^w(1)$	$q^d(0)$	$q^d(1)^\dagger$	$q^w(0)$	$q^w(1)$	$q^d(0)$	$q^d(1)^\dagger$	μ_1	μ_2	μ_4	μ_5	μ_7	μ_8	μ_9	μ_{11}
	$\bar{R}^2$	0.00	0.00	0.00	0.01	-0.02	0.01	0.00	-0.01	0.00	0.00	-0.01	-0.01	-0.01	0.00	0.00	0.00
Sweden	p-value	0.60	0.55	0.40	0.19	0.93	0.13	0.46	0.66	0.44	0.37	0.86	0.73	0.71	0.55	0.58	0.40
	$\bar{R}^2$	-0.01	0.00	-0.01	0.00	-0.02	0.02	0.00	-0.01	0.00	0.01	-0.01	-0.01	-0.01	-0.01	0.02	0.00
Belgium	p-value	0.72	0.54	0.98	0.31	0.98	0.07	0.31	0.66	0.50	0.28	0.88	0.85	0.87	0.73	0.08	0.34
		-0.00	0.00	-0.01	-0.00	-0.01	-0.00	-0.01	-0.01	-0.01	-0.01	-0.00	-0.01	-0.01	-0.00	0.01	-0.00
France		0.63	0.35	0.72	0.63	0.87	0.54	0.74	0.84	0.86	0.88	0.47	0.62	0.69	0.55	0.26	0.56

†For Sweden the test is for the parameter $q^d(1,1)$

Country		ARCH Test							
		ω_1	ω_2	ω_3	ω_4	ω_5	ω_6	ω_7	ω_8
	$\bar{R}^2$	-0.02	0.02	0.00	0.01	0.01	-0.01	0.02	0.00
Sweden	Prob	1.00	0.09	0.35	0.22	0.26	0.59	0.13	0.57
	$\bar{R}^2$	-0.01	0.01	0.00	0.00	-0.01	-0.01	0.04	-0.01
Belgium	Prob	0.87	0.18	0.49	0.51	0.72	0.83	0.02	0.75
	$\bar{R}^2$	-0.02	-0.00	-0.01	-0.01	-0.02	-0.02	0.04	-0.01
France	Prob	0.92	0.48	0.80	0.71	0.97	0.92	0.01	0.76

3.1.3 Diagnostic results for France

For France the AR-test rejects the last AR-test at the 1% level and the next to last is close to being rejected. There thus seem to be some domestic autocorrelation left to explain. As in the previous cases, an extreme realization seems to be accountable for the rejection – in January 1988 the realized return was -17%. After including a dummy for this observation, no test is rejected at the 1% level, although next to last ARCH test is fairly close at a nominal p-value of 1.5%. The parameter estimates did not change very much after the re-estimation

4. Results

The estimated parameters together with asymptotic standard errors, calculated from the Hessian of the loglikelihood function, are presented in *Table* 3. The estimates for the world process varies somewhat between the different estimations despite of the fact that the same values for world returns are used in all estimations. These differences are due to that also the domestic returns contain information about the world state process and thus affect the estimation of its parameters.

Common for all the estimations is that the low risk state is more persistent than the high risk state, both for the world and the domestic state processes. This also means that economies spends most of the time in the low risk state. The unconditional probability of the low risk state is around 0.8 for all state processes[6]. The estimated probability of staying in the world high risk state is, although lower than the probability of staying in the low risk state, as high as between 0.72 and 0.82. This means that a switch to the high risk state is something more than just one extreme realization of returns. This is also true for the domestic processes. For Sweden we find evidence that that it is more likely to stay in the high risk state given that it has continued at least two months. About half of the times a switch to domestic high risk state, is

[6] In the case with a first order Markov chain the unconditional probability of being in state 0 is $((1\text{-}q(1))/(2-q(1)\text{-}q(0))$. In the case of second order Markov chain, as for Sweden, one can iterate on the transition matrix for the state to calculate the unconditional probability of state 0. For Sweden this is 0.85.

followed by an immediate shift back. If this does not occur, the high risk state is expected to continue for another 7 months.

The drift parameters for the world return are estimated with rather good precision and stability over the different estimations. From the negative and large value of μ_3 we see that there is a large fall in the stock market when the high risk state is entered. This adds a negative (positive) component to expected returns in the low (high) risk state. On the other hand, the drift term μ_2 is negative adding a negative component to expected returns in the high risk state. This outweighs the effect due to μ_3 so expected returns are lower in the high risk state.

The precision in the drift terms for domestic returns is lower. For Sweden, only μ_6, (μ_8) and μ_{10} are significant at conventional significance levels. We find that the also the Swedish market falls when the world risk state shifts to high risk. A shift to the domestic high risk state has a quantitatively similar effect, the point estimates are -7.0% and -8.3%. The negative value for μ_8 means that the effect of the world high risk state on expected Swedish returns has become more negative over time. This could be an effect of the extensive capital market liberalization that has taken place in Sweden during the sample periods.

Also the drift terms for the return in Belgium and France are estimated with low precision. A notable result is, however, that μ_6 is significantly negative and large in absolute value for all three countries. The effect of a shift to high volatility on the world stock market is thus a large fall on all domestic stock market. Except for μ_6, only μ_{10} in Belgium is significant. It is positive and relatively large.

The parameters capturing the volatility of the news process are estimated with better precision than the drift parameters. The standard deviation of the news process at the world market is estimated to be between 1.8% and 2.6% higher in high risk state than in the low. This amounts to somewhat less than a doubling of the standard deviation. The increase is significant, and strongly so when we consider Belgium and France.

Turning to the domestic markets and focusing on the influence of the world news process we find both important differences and similarities between the markets. First, ω_5 is positive and significant in Sweden. There is thus strong evidence of an increasing Swedish sensitivity to the world stock market. If such a trend exists in the other two countries, it is of much less importance. Second, in all countries, ω_4 is positive and significant indicating that the foreign influence is substantially larger during international high volatility periods. This tendency is largest for Belgium, followed by Sweden. We see that for all the estimations ω_4 is larger than ω_2. A high volatility period on the world market thus has larger effects on domestic volatility than on world market volatility. Conversely, ω_3 is smaller than ω_1 for all estimations indicating that the world influence is relatively low when the world market is in a state of calmness. The foreign influence on the Swedish market during international low volatility periods was not even significant during the beginning of the sample.

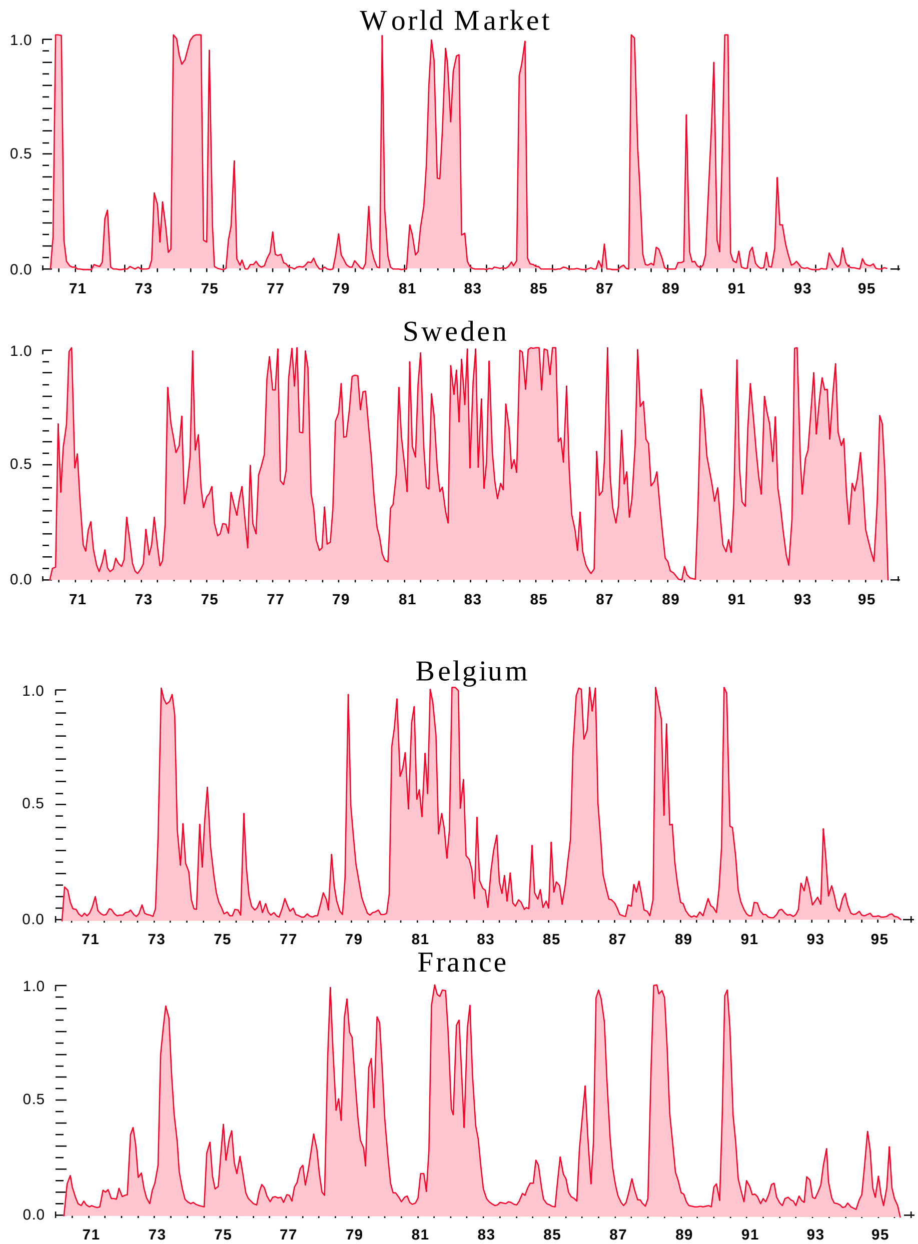
Table 3 Estimated Parameters - Final Models

	Sweden		Belgium		France	
$q^w(0)$	0.964	(31.06)	0.912	(31.48)	0.921	32.10
$q^w(1)$	0.815	(13.28)	0.715	(11.92)	0.774	12.59
$q^d(0)$	0.975	(21.45)	0.960	(26.32)	0.940	13.94
$q^d(1,0)$	0.471	(1.85)	-	-	-	-
$q^d(1,1)$	0.862	(8.65)	-	-	-	-
$q^d(1)$	-	-	0.844	(14.10)	0.830	(10.03)
μ_1x100	0.847	(3.89)	0.671	(3.07)	0.683	(3.12)
μ_2x100	-3.652	(-3.40)	-1.754	(-1.98)	-1.646	(-1.95)
μ_3x100	-9.397	(-6.41)	-7.192	(-7.26)	-7.084	(-6.87)
μ_4x100	0.325	(0.53)	0.717	(1.42)	-0.401	(-0.37)
μ_5x100	0.287	(0.18)	-0.884	(-0.63)	-1.413	(-0.78)
μ_6x100	-6.997	(-3.32)	-4.582	(-3.34)	-5.192	(-3.10)
μ_7x100	1.057	(1.01)	-0.108	(-0.14)	0.664	(0.48)
μ_8x100	-5.170	(-1.73)	0.843	(0.44)	2.313	(0.83)
μ_9x100	-2.117	(-0.52)	-1.010	(-0.44)	2.934	(1.00)
μ_{10}x100	-8.307	(-3.16)	5.678	(3.33)	3.917	(1.17)
μ_{11}x100	6.174	(0.58)	1.660	(0.39)	-2.524	(-0.52)
ω_1x100	3.162	(17.34)	2.715	(14.33)	2.724	(13.80)
ω_2x100	1.801	(2.24)	2.539	(4.92)	2.572	(5.09)
ω_3x100	0.982	(1.54)	1.194	(2.14)	2.429	(3.04)
ω_4x100	3.095	(2.92)	3.814	(4.55)	3.931	(3.19)
ω_5x100	3.169	(3.14)	1.350	(1.74)	0.695	(0.68)
ω_6x100	3.860	(7.99)	3.185	(8.73)	4.826	(7.66)
ω_7x100	3.358	(2.79)	3.139	(3.58)	3.360	(3.77)
ω_8x100	0.767	(0.88)	-0.431	(-0.73)	-1.994	(-2.13)
Dummy	-10.048	(-1.98)			-18.968	(-4.85)

† Parameter estimates divided by asymptotic standard deviation in parenthesis. Standard deviations calculated from Hessian of log-likelihood function.

The domestic news process is of strong importance for all the domestic markets. Both ω_6. and ω_7 are large and significant for all three countries. Also the domestic state process seems to have been of substantial importance throughout the sample. The standard deviation of domestic news doubles in the domestic high risk state in Sweden and Belgium. The increase is slightly smaller in France, but still clearly significant. France also stands out from the other two by having a strong and significant negative trend in the volatility of domestic news. No such trend can be found on the Swedish stock market.

Figure 2 State Probabilities



An output from the estimation of the regime switching model is probabilities of being in the high risk states, conditional on realized returns. The probabilities of being in the two high risk states for each period t, conditional on realization up to $t+1$ are plotted in *Figure* 2.[7,8]. One important observation stands out immediately from the graphs. This is that the domestic state processes in Belgium and France seems to be almost identical. The Swedish states, on the other hand, are not at all synchronized with the other state processes.

5. Conclusion

I have in this paper applied the Hamilton regime switching model to bivariate stock market data. The results regarding volatility transmission are fairly clear-cut;

1. The increased volatility on the Swedish stock market can be attributed to an increased sensitivity to the world markets and not to increased domestic news flows. Such a trend cannot be found in France and Belgium.
2. During a high volatility period on the world market, which has an expected duration of around 5 months, the domestic sensitivity to the world market increases in all three studied countries. This means that the increase in volatility is larger on the domestic than on the world market.
3. Domestic volatility show clear evidence of shifting levels of volatility in all three countries.

The results regarding the drift terms, i.e., expected return conditional on the realized state are estimated with lower precision. One clear results stands out, however, i.e., when the world market goes into a period of high volatility, both domestic and world markets falls simultaneously. The fall is large – in the order of 5 to 8 %. What we thus see is that occasionally the world market is hit by a large negative shock. This shock has a similar effect

[7] The smoothed probabilities, based on the full sample, has for computational reasons not been calculated.

[8] The Swedish state probabilities are somewhat sensitive to the choice of model. The preliminary model, with first order state Markov chains. produced probabilities that generally where closer to zero.

on the level of the domestic markets. After the shock the world market is more volatile over an extended period of time and the domestic markets are substantially more sensitive to the world markets than otherwise.

The finding of relatively large variations in the intensity of the news flow from the stock market may have important macroeconomic implications. A shift to a high level of news flow from the stock market may be important also for households that do not own shares. Certainly, there are other ways a consumer can be affected by changes in expected future firm profits than from its associated capital gains. It seems more than likely the information flow from the stock market may contain information about future wages, prices or growth rates, for example. In Hassler (1995) I show that there is evidence of a link between financial volatility and durables demand. When financial volatility increases durables purchases fall substantially while non-durables demand seems to be largely unaffected. In Hassler (1996) this is given a structural interpretation: High stock market volatility implies a high current flow of information. Given that investments in durables involve some degree of irreversibility, the value of waiting to purchase a new durable increases in the current flow of information. Increased volatility should then lead to a higher tendency to postpone purchases. What it is exactly, in the news flow from the stock market that is important for, say, a representative household is of course an open question.

Another open question is the reason for why the Swedish stock market have become more sensitive to the world market. As noted above, results in this paper do not point in the direction of a changed pricing behavior on the stock market but rather that the underlying fundamental, i.e., expected future firm profits, have become more sensitive to the world developments. Given that the model in this paper has low precision in the pricing parameter, i.e., the μ's, this conclusion is not strongly founded and needs more examination.

Lastly, some words about the modeling approach. The model in this paper is highly stylized in the sense that we only allow for two states of volatility. In reality there may, of course, be many more states. The model does, however, seem to be well suited to detect shifts in the news processes that drive the stock market. It also survives the rather extensive testing I have performed. Alternative models of ARCH type may instead tend to blur the distinction between low and high volatility periods. Which class of model performs best in terms of describing the data is, however, certainly an open question. Although such comparisons is outside the scope of this paper, one can be sure that they will be done with scrutiny in the near future.

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Appendix

In this appendix I use a standard asset pricing model to derive the process for asset prices when the volatilities of the underlying stochastic news or dividend processes follow two-state processes. |Assume that the world dividend process follows

$$\begin{aligned} \ln d_{t+1}^{w} &= \ln d_{t}^{w} + \bar{\mu}^{w} + \mu^{w} s_{t+1}^{w} + (\omega_1 + \omega_2 s_{t+1}^{w})\varepsilon_{t+1}^{w} \\ E_t \varepsilon_{t+1}^{w} &= 0,\ E_t\left((\varepsilon_{t+1}^{w})^2\right) = 1 \end{aligned} \tag{A.1}$$

where d_t^w is the aggregated dividend of the world market at time *t*. Furthermore, assume that the world risk state follows a first order stationary Markov chain with the probability of staying in each state given by $q^w(s_t^w)$.

The representative world agent maximizes a standard CRRA objective function $E_t \sum_{s=0} \beta\, c_{t+s}$. Assume that *c*=*d* in each period. Then the price process of the world stock market index must satisfy

$$\tilde{p}\left(s_t^w, d_t^w\right) = E_t\left[\left(\tilde{p}\left(s_{t+1}^w, d_{t+1}^w\right) + d_{t+1}^w\right)\beta\left(\frac{d_{t+1}^w}{d_t^w}\right)^{-\alpha}\right]. \tag{A.2}$$

Since time *t* expected future dividends are linear in d_t^w and expected MRS are independent of d_t^w it follows that stock market index is linear in d_t^w. Dividing both sides of the pricing relation by d_t^w and using the linearity of the price index we find that price dividend ratio only depends on the current state and satisfies

$$\frac{\tilde{p}\left(s_t^w, d_t^w\right)}{d_t^w} \equiv p\left(s_t^w\right) = E_t\left[\left(p\left(s_{t+1}^w\right) + 1\right)\beta\left(\frac{d_{t+1}^w}{d_t^w}\right)^{1-\alpha}\right] \tag{A.3}$$

Furthermore, the return, defined as $r_{t+1} \equiv \ln\left(p\left(s_{t+1}^w\right)+1\right)d_{t+1}^w - \ln p\left(s_t^w\right)d_t^w$, satisfies

$$\begin{aligned} r_{t+1} &= \ln\left(p\left(s_{t+1}^w\right)+1\right) - \ln p\left(s_t^w\right) + \ln\frac{d_{t+1}^w}{d_t^w} \\ &= \ln\left(p\left(s_{t+1}^w\right)+1\right) - \ln p\left(s_t^w\right) + \bar{\mu}^w + \mu^w s_{t+1}^w + (\omega_1 + \omega_2 s_{t+1}^w)\varepsilon_{t+1}^w \end{aligned} \tag{A.4}$$

The real risk-free rate is also determined by the current state;

$$\bar{r}_{t+1}^w\left(s_t^w\right) = -\ln E_t\left[\beta\left(\frac{d_{t+1}^w}{d_t^w}\right)^{1-\alpha}\right] \tag{A.5}$$

We can now write the excess return in regression form

$$r_{t+1}^w - \bar{r}_{t+1}^w = \mu_1 + \mu_2 s_t^w + \mu_3 \Delta s_{t+1}^w + (\omega_1 + \omega_2 s_{t+1}^w)\varepsilon_{t+1}^w. \tag{A.6}$$

Here it should be noted that the three μ_i in (2.1) are not sufficient to identify the two state prices and the drift parameters $\bar{\mu}^w$ and μ^w. Knowledge of, for example the risk aversion α, could identify all parameters and thus disentangle the risk premium component of expected returns. This is not of prime interest in this context and (2.1) is in any case a valid regression to run and ω_1 and ω_2 are identified.

Now turn to a domestic stock market. The return on the domestic market is assumed to be driven by both the world news to dividends and by an idiosyncratic domestic news process.

$$\begin{aligned} &\ln d_{t+1}^d = \ln d_t^d + \bar{\mu}^d + \mu^{d,w} s_{t+1}^w + (\omega_3 + \omega_4 s_{t+1}^w)\varepsilon_{t+1}^w + \mu^{d,d} s_{t+1}^d + (\omega_5 + \omega_6 s_{t+1}^d)\varepsilon_{t+1}^d, \\ &E_t \varepsilon_{t+1}^d = E_t \varepsilon_{t+1}^d \varepsilon_{t+1}^w = 0,\ E_t\left((\varepsilon_{t+1}^d)^2\right) = 1 \end{aligned} \tag{A.7}$$

The influence of the foreign news process is allowed to shift with the international risk state. Also the intensity of the domestic news process is allowed to shift as a domestic risk state, denoted s_t^d shifts. The domestic risk state follows a Markov chain with continuation probabilities $q^d(s_t^d)$, so it is assumed to be independent of, in particular, the world risk state.

The price of the domestic asset is linear in d^d so if the asset is priced by a world investor consuming d^w

$$p\left(s_t^w, s_t^d\right) = E_t\left[\left(p\left(s_t^w, s_t^d\right) + 1\right)\frac{d_{t+1}^d}{d_t^d}\beta\left(\frac{d_{t+1}^w}{d_t^w}\right)^{-\alpha}\right] \tag{A.8}$$

while if the price setter is domestic and restricted to consume d^d it is

$$p\left(s_t^w, s_t^d\right) = E_t\left[\left(p\left(s_t^w, s_t^d\right) + 1\right)\beta\left(\frac{d_{t+1}^d}{d_t^d}\right)^{1-\alpha}\right]. \tag{A.9}$$

To allow a trend in volatility in the simplest possible way, I allow a deterministic time trend in the volatility of the innovations to the domestic dividend process as well as to the drift terms and their sensitivity to the risk states. The final bivariate model is then given by (2.2).