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Bo Danø

Exchange Rate Exposure in Denmark

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**Exchange Rate Exposure
in Denmark**

Bo Danø

Exchange Rate Exposure in Denmark

Copenhagen Business School
The PhD Program in Business Economics
Ph.D. Series 16.2003

Bo Danø
Exchange Rate Exposure in Denmark

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Exchange Rate Exposure in Denmark

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Ph.D. Dissertation
April 2003

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Chapter 1

Introduction to the Thesis

1 Introduction

The purpose of this introductory chapter is to discuss the relation between the literature on exchange rate exposure - broadly defined as the relation between exchange rates and the value of firms - and pricing of exchange rate risk, and the chapters contained in this thesis, that is, to discuss where and how the chapters fit in. In this context, this chapter contains a summary of the literature focussing mainly on the empirical methods and results, since these are the common denominator of the chapters. Naturally, surveys of the literature already exist, see e.g. Talasmaki (1999). However, I feel that a survey will serve to clarify where and how the chapters fit in and enhance the readability of the thesis. The chapters are written fairly independently and can by large be read as such, but the ordering of the chapters to some extent reflects the evolution of the literature and hopefully document the skills acquired during the enrollment in the Ph.D.- program at the Copenhagen Business School.

This introductory chapter is organized as follows: Section 2 contains a review of some recent theoretical contributions, that have investigated how various factors affect exchange rate exposure for firms operating in different markets. Subsequently, section 3 reviews the foundations for the regression approach to exchange rate exposure, which constitutes the common framework applied by a

large number of contributions to the empirical research and which is the point of departure for the second chapter of the thesis. Previous empirical research based on the regression approach as well as on different augmentations of this approach is then reviewed in section 4 and 5, and section 6 summarizes chapter 2 and chapter 3. Finally, section 7 contains a summary of chapter 4 and chapter 5.

2 Various determinants of exchange rate exposure

The literature on exchange rate exposure is a branch of financial economics concerned with the sensitivity of the value of firms to exchange rate movements. In the light of the increased volatility of exchange rates since the beginning of the seventies and the rapid globalization of the business environment over the past decades, this issue has attracted substantial attention in academic research and is a source of concern for corporations. In particular, the high volatility of exchange rates as compared with other macroeconomic variables such as inflation and interest rates, implies that exchange rate movement can be a major source of uncertainty for firms, that can affect the value of firms and the cost of capital and can have implications for the actions taken by firms, such as hedging decisions.

In the literature a distinction is often made between accounting exposure and economic exposure. Accounting exposure is the extent to which exchange rate movements cause gains or losses on the accounting statements and is often divided into translation exposure and transaction exposure. Translation exposure is the effect of exchange rate movements on the home currency value of foreign assets and liabilities, and transaction exposure generally denotes the balance of known payments and receivables in foreign currency. However, the concept of accounting exposure does not include effects of exchange rate movements on firm value that are not directly recorded on the accounting statements. For example, exchange rate movements may affect expected profits and hence the value of firms through

changes in expected demand for the product of the firm, through changes in the actions of the firm because of movements in exchange rates etc., so that even firms with no accounting based exchange rate exposure may be affected by exchange rate fluctuations.

On a theoretical level several contributions have examined how various factors affect economic exchange rate exposure, often and hence also in this thesis simply referred to as exchange rate exposure, for firms operating in different markets. More recent models include Levi (1994), Marston (1996), Bodnar et al. (1998) and Allayannis and Ihrig (2000), among others. Although these contributions apply somewhat different frameworks, the point of departure is generally some form of present value model in which the value of the firm is related to exchange rates. Following Marston (1996) and Bodnar et al. (1998), this can be illustrated by expressing the value of a firm or a portfolio of firms, V , in terms of a stream of present and infinite future cash flows, i.e. as
$$V = \sum_{t=1}^{\infty} \frac{CF_t}{(1+\rho)^t}$$

, where CF_t is the cash flow of the firm, equal to after-tax profits plus net investment and ρ is the discount rate. Assuming for simplicity that net investment is equal to zero and that cash flows are constant from period to period, the present value can be expressed as
$$V = \frac{CF}{\rho} = \frac{\pi}{\rho}$$
, where π is after-tax profits. With

constant discount rate, exchange rate exposure can then be expressed as the derivative
$$\frac{dV}{dS} = \frac{1}{\rho} \frac{d\pi}{dS}$$
, where S is the exchange rate. In this context exchange rate exposure is proportional to the derivative of current profits with respect to the exchange rate.

While the different models generally are based on some form of present value framework like the above, the contributions differ along a number of

dimensions, both with respect to the assumptions regarding on which markets the firms operate, the competitive setting, the focus on different factors that influence exposure and the solution techniques applied. With respect to the assumptions regarding on which markets the firms operate, several authors have considered the case of an exporting firm, that either produces all of its products at home without imported inputs, cf. for example Levi (1994), or that imports some of its inputs for production, cf. for example Marston (1996) and Bodnar et al. (1998). Furthermore, Levi (1994) also considers the case of an importing firm which buys a homogeneous product in different foreign markets and sells the product in the home country, and Marston (1996) and Bodnar et al. (1998) incorporate an import-competing firm with cost based in the home currency in their analysis. Allayannis and Ihrig (2000) focus on neither exporting nor importing firms, but rather consider a firm that uses imported intermediate inputs and capital to produce output for sale both domestically and abroad. As for the competitive setting and the focus on different factors that influence exposure, Levi (1994) considers an exporting and an importing firm separately, allowing the demand elasticity and other variables to vary in each case. Marston (1996) and Bodnar et al. (1998) primarily focus on a duopoly setting, where the exporting firm competes with the local firm on the foreign export market and where there is some degree of substitution between the products of the two firms. While Marston (1996) stresses the importance of the competitive structure of the industry in which the firm operates and derives the effect of exchange rate movements on the value of firms under different forms of competition, such as Cournot competition, Stackelberg leadership either by the exporting firm or by the local firm and in the situation, where each firm takes the output response of the other firms into account when formulating its own output decisions, i.e. the case of consistent conjectures, Bodnar et al. (1998) primarily focus on the relation between exchange rate

exposure and pass-through, linked through the degree of product substitutability. Allayannis and Ihrig (2000) treat the firm as a monopolist and highlight three channels of exposure, i.e. through the competitive structure of the markets where final output is sold, through the interaction of the competitive structure of the export market and the share of production that is exported and through the interaction of the competitive structure of the imported input market and the share of production that is imported. Finally, with respect to the solution techniques applied, Marston (1996) and Bodnar et al. (1998) use specific functional forms for the demand or utility functions, which are applied to reduce the exposure, profit and pass-through equations to exogenous parameters, and Allayannis and Ihrig (2000) encompass the output of other firms' in the values of markups, revenues etc.

The different assumptions invoked in the various theoretical models imply that the exact relation between exchange rates and firm value naturally varies with the assumptions made regarding on which markets the firms operate, the competitive setting, the focus on different factors that influence exposure as well as the solution techniques applied. Since the relation between firm value and exchange rates is quite complex and potentially influenced by numerous factors, I have chosen to conduct the discussion of variables that influence exchange rate exposure in the context of exporters, importers and import-competing firms, respectively.

As for the case of an exporter, consider - as a point of departure - a monopolistic firm which exports its product and imports some of its inputs for production. In this case, a depreciation (appreciation) of the home currency increases (decreases) the value of the firm, and exchange rate exposure is proportional to the level of the net revenue based on foreign currency, cf. Marston (1996). More generally however, the extent to which the value of an export firm

increases (decreases) with a depreciation (appreciation) of the home currency depends on a number of factors, such as the elasticity of demand, possibly related to the degree of competition, cf. for example Levi (1994), Marston (1996) and Bodnar et al. (1998). With some degree of competition with local firms in the foreign export market, the extent to which the exporter is exposed to exchange rates depends on the degree to which the exporter is able to change prices when the exchange rate changes. If the demand elasticity is high, the exporter will be relatively unable to counteract the effect of exchange rate changes on firm value through a change in the price on the foreign export market, and the exporter will be more exposed to changes in exchange rates, as compared with a situation where demand is less elastic. That the degree of exchange rate exposure for an exporter is related to the elasticity of demand and the price response of the firm, is also highlighted by Bodnar et al. (1998). In particular, the model in Bodnar et al. (1998) captures two different impacts of an exchange rate change on the exporter's profits, namely the impact on profits on the original profit margin, which includes both the effect on the domestic currency value of total expenditures and the effect on the exporter's market share, and the impact on the domestic profit margin, partly induced by a less than proportionate effect of exchange rate changes on the exporter's price in foreign currency, i.e. by less than full pass-through, cf. also Knetter (1994). In this framework, there is an inverse relation between pass-through and exchange rate exposure measured as a percentage of firm value, linked through the degree of product substitutability. Specifically, a higher degree of substitutability of the product between the exporting and the import-competing firms' products raises the elasticity of demand faced by the exporter, resulting in a lower degree of pass-through of exchange rate changes into foreign currency prices. On the other hand, since an increase in the demand elasticity results in lower markups and smaller profits, a higher degree of product substitutability

increases exchange rate exposure measured as the percentage of firm value, resulting in an inverse relation between exposure and pass-through. Somewhat similar results are derived by Allayannis and Ihrig (2000), who show that industries characterized by a higher degree of competition on the foreign export market, corresponding to industries with low markups on the export market, are more exposed to exchange rate movements. Apart from the above mentioned channels, factors such as the cost structure of the firms, the location of production facilities and more generally the amount of foreign currency denominated liabilities etc. also influence the extent to which exporters are exposed to exchange rate movements. In particular, an exporter can dampen exchange rate exposure by having cost denominated in the foreign currency. In the case where the exporter's foreign currency-denominated liabilities are equal to the present value of the after-tax foreign currency profit in the particular export market, times the demand elasticity on that market, exchange rate movements do not impact on the value of the firm, cf. Levi (1994).

Considering the case of an importing firm which buys a homogeneous product on different foreign markets and sells the product in the home country, Levi (1994) shows that a depreciation (appreciation) of the home currency decreases (increases) the value of the firm, provided that the firm operates where demand is sufficiently elastic. Furthermore, parallel to the case of an exporting firm, the more elastic the demand is, the larger is the extent to which the value of the importing firm decreases (increases) with a depreciation (appreciation) of the home currency. Although Allayannis and Ihrig (2000) do not focus on pure importers, they relate exchange rate exposure to the interaction between the competitive structure of the imported input market and the share of production that is imported. Specifically, Allayannis and Ihrig (2000) argue that, other things being equal, firms with a higher share of imported inputs and a larger elasticity of

demand for imported inputs are affected more negatively by a depreciation of the home currency. As for the case of an import-competing firm, with both revenues and costs based in its own currency, Marston (1996) shows that when the demand curve is downward sloping, a depreciation (appreciation) of the home currency increases (decreases) the value of the firm.

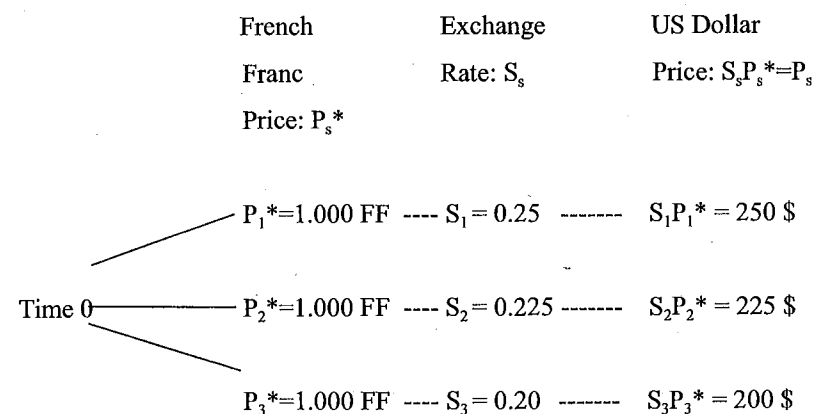
3 Measuring exchange rate exposure

In the empirical literature exchange rate exposure is commonly estimated by applying various specifications of the regression approach suggested by Adler and Dumas (1984), cf. Jorion (1990), Bodnar and Gentry (1993), Amihud (1994), Levi (1994), Khoo (1994), Choi and Prasad (1995), Allayannis (1996), Donnelly and Sheehy (1996), Chamberlain et al. (1997), Chow et al. (1997), Allayannis (1997), Miller and Reuer (1998), He and Ng (1998), Talasmaki (1999), Friberg and Nydahl (1999), Allayannis and Ofek (2001), Williamson (2001), among others. Since expected exchange rate movements presumably already are incorporated into present values, the regression approach captures the contemporaneous correlation between market values and unexpected exchange rate changes, illustrated by the following example¹. Assume for simplicity a world with two currencies, US dollars and French francs. Furthermore, assume that the exchange rate vis-a-vis France is random, and that a representative US investor expects with certainty to receive 1.000 franc in three months from today. Since 1.000 franc represent the sensitivity of the future dollar value of the franc balance to variations in the exchange rate, the investors exposure to exchange rate variations on the target data three months away is 1.000 franc. This corresponds to the regression coefficient on the future dollar value of the franc position in a regression of that position on the exchange

¹ Cf. Adler and Dumas (1984), p. 44- 45.

rate. To see this, assume for simplicity, that there are three possible future states of nature. From the view point of time $t=0$ to the future target date, the dollar value of the French asset is uncertain and uncertainty is captured by the fact that one out of three possible states of nature, subscribed by s , will occur. In each state the French asset will have a franc price denoted by P_s^* , in this example 1.000 franc in each state. The exchange rate, S_s , is uncertain and will take on different values in each future state of nature. Therefore, the dollar value of the French asset, $P_s = S_s P_s^*$, is random. In particular, assume that each state is equally likely to prevail, i.e. that the state probability is $1/3$, and that $S_1 = 0.25$, $S_2 = 0.225$ and $S_3 = 0.20$. The example is illustrated in Figure 1.

Figure 1: The Dollar Price of a Risky Foreign Asset in Three States of Nature



Source: Adler and Dumas (1984).

Consider the linear regression of P on S , i.e. $P = a + bS + e$, where $b = \text{Cov}(P,S)/\text{Var}(S)$. $\text{Cov}(P,S) = \sum_s p_s (P_s - \underline{P})(S_s - \underline{S})$, where p_s is the probability of state s , P_s is the dollar price in state s , $\underline{P} = \sum_s p_s P_s$ and $\underline{S} = \sum_s p_s S_s$. Applying the figures from above, $\underline{S} = 0.225$ and $\underline{P} = 225 = 1000\underline{S}$, so that $\text{Cov}(P,S) = 0.416$. $\text{Var}(S) = \sum_s p_s (S_s - \underline{S})^2 = (2/3)(0.000625)$, so that $b = \text{Cov}(P,S)/\text{Var}(S) = 1.000$, which is the representative investor's exposure to exchange rate variations at the target date.

More generally, consider a random dollar price, P , of a risky asset on a given future date². The number of states of nature, k , is finite with known probabilities. In a given state, k , the outcome P_k is associated with a vector of state variables, $S_k = \{S_1, \dots, S_n\}_k$. Exposure of P to S_1 is then defined as $E(\partial P / \partial S_1)$, i.e. as the current expectation, across future states of nature, of the partial sensitivity of P to S_1 , the effects of all other variables held constant. Assuming that P and S are jointly normal, $E\{\partial E[g(P)|S] / \partial S\} = \text{cov}[g(P), S] / \text{var}(S) = E[g'(P)] b_{ps}$, where $g(P)$ is a contingent claim on P , S is the single state variable and b_{ps} is the regression coefficient of P on S , cf. Rubinstein (1976) and Adler and Dumas (1980). Since $g'(P) = 1$, $E(\partial P / \partial S_1) = E\{\partial E[P|S] / \partial S_1\} = \text{cov}[S_1, P|S] / \text{var}(S) = b_{ps(i)S}$, where $b_{ps(i)S}$ is the partial regression coefficient on S_1 in a regression of P on S . In other words, exchange rate exposure can be measured as the coefficient of the purchasing power variable in a linear regression of an asset's future domestic-currency market price on the contemporaneous foreign exchange rate³. The approach decomposes the probability distribution of a risky asset's domestic currency price at a future instant into two parts: one part that is correlated with the exchange rate and another part

² This paragraph follows the appendix in Adler and Dumas (1984).

³ Extending the regression approach suggested by Adler and Dumas (1984) to a setting with many currencies, Schnabel (1989) subsequently proves that exchange rate exposure can be measured within a multiple regression model.

that is independent of the exchange rate. As noted by Adler and Dumas (1984), this decomposition does not imply any causal relation, since market values and exchange rates are endogenously determined.

According to the regression framework proposed by Adler and Dumas (1984), exchange rate exposure is estimated by the slope coefficient in a linear regression of the value of a firm or a portfolio of firms on exchange rates, and the various empirical applications of the approach include changes in stock values as a measure of changes in the value of firms as well as changes in exchange rates. In the majority of empirical studies, exchange rate exposure is estimated on monthly data, cf. among others Jorion (1990), Bodnar and Gentry (1993), Khoo (1994), Choi and Prasad (1995), Donnelly and Sheehy (1996), Allayannis (1997), Miller and Reuer (1998), He and Ng (1998), Friberg and Nydahl (1999), Allayannis and Ofek (2001) and Williamson (2001), applying either nominal variables, cf. for example Bodnar and Gentry (1993), Khoo (1994), Chamberlain et al. (1997), Friberg and Nydahl (1999) and Allayannis and Ofek (2001) or real variables, cf. Levi (1994), Allayannis (1997), Miller and Reuer (1998) and Williamson (2001). A rationale for using real variables is that both changes in nominal exchange rates as well as movements in prices may affect exchange rate exposure. Furthermore, if the law of one price holds, then exchange rate fluctuations are exactly offset by price movements, and exchange rate risk vanishes, cf. for example Shapiro (1975). On the other hand, an argument for applying nominal variables is, that since nominal exchange rates are readily observable, it is less demanding to assume that the financial markets correctly observe nominal exchange rates, as compared with real exchange rates, cf. Bodnar and Gentry (1993). However, while the distinction between real and nominal variables may matter in principle, the high monthly volatility in exchange rates as

compared with the monthly variability in inflation rates, implies that most of the monthly movements in exchange rates cannot be accounted for by inflation rates, cf. also Mark (1990). As a result, similar results are typically obtained using nominal or real variables, cf. Amihud (1994), Choi and Prasad (1995) and Friberg and Nydahl (1999), and the discussion contained in Jorion (1990), Chamberlain et al. (1997) and Allayannis and Ofek (2001), among others.

4 Exchange rate exposure in the United States

For firms on the stock market in the United States, previous research have applied various specifications of the regression framework to investigate the significance of exposure and various factors that influence exposure, on market-index data (Adler and Simon (1986) and Ma and Kao (1990)) or for particular samples of industries or firms, including multinationals (Jorion (1990) and Choi and Prasad (1995)), large exporters (Amihud (1994)), firms in the industry with the highest net-export to sales ratio (Allayannis (1996)), non-financial firms (Allayannis and Ofek (2001)), firms in the automotive industry (Williamson (2001) and Allayannis (1996)), manufacturing firms (Miller and Reuer (1998) and Allayannis (1997)), banking institutions (Chamberlain et al. (1997)) and broader sample of industries (Bodnar and Gentry (1993)).

However, these studies have met limited success in documenting significant, contemporaneous exchange rate exposure. Specifically, Jorion (1990) finds that only about 5 percent of a sample of 287 multinational firms are significantly exposed, Amihud (1994) finds no significant exposure for a sample of the largest exporters and Allayannis (1996) only finds limited evidence of significant, contemporaneous exposure for the industry with the highest net-export to sales ratio, i.e. the electronic computers industry. Somewhat stronger evidence of significant exposure for the stock market in the United States is provided by Choi

and Prasad (1995), who find that about 15 percent of their sample of multinationals are significantly exposed. Furthermore, Bodnar and Gentry (1993) show that 11 out of a sample of 39 industries in the United States have exposures that are statistically significant, Miller and Reuer (1998) find that 13-17 percent of their sample of manufacturing firms are significantly exposed, Chamberlain et al. (1997) document significant exposure for 17-30 percent of firms in a sample of bank holding companies and Williamson (2001) finds significant exposure for a sample of automotive firms in the United States. With respect to factors that influence exchange rate exposure, several studies have found that a higher ratio of foreign sales to total sales implies a stronger, contemporaneous correlation between a depreciation (appreciation) of the dollar and an increase (decrease) in stock market values, cf. among others Jorion (1990), Bodnar and Gentry (1993), Amihud (1994), Allayannis (1997), Williamson (2001) and Allayannis and Ofek (2001). Bodnar and Gentry (1993) and Allayannis (1997) show that a higher import ratio implies a more pronounced correlation between an appreciation of the dollar and an increase in stock market values. In addition, Williamson (2001) finds that foreign production decreases exposure, consistent with the idea that an exporter can counteract the sensitivity of the cash flow to exchange rate movements by having costs denominated in the local currency, cf. also Miller and Reuer (1998), and that the nature of competition is an important determinant of exchange rate exposure, as pointed out on a theoretical level by Marston (1996). Allayannis and Ofek (2001) show that the use of derivatives significantly reduces exposure and find evidence in support of the hypothesis that firms use derivatives and foreign debt as a hedge against exchange rate movements, providing one possible explanation for the limited success of the previous research in finding significant, contemporaneous exposure for firms on the stock market in the United States.

4.1 Time-varying exchange rate exposure

Since the numerous factors that may influence exchange rate exposure are not constant through time, several authors have conjectured that exchange rate exposure may be time-varying, cf. Jorion (1990), Levi (1994), Amihud (1994), Allayannis (1997) and Williamson (2001), among others. In particular, based on an ex-ante division of the sample period into different sub-periods, both Jorion (1990) and Amihud (1994) find that the sign as well as the significance of exposure are different in the various sub-periods, and Williamson (2001) relates evidence of time-varying exposure in the automotive industry to changes in the competitive structure of this industry. Furthermore, Allayannis (1997) is able to reject the hypothesis that exchange rate exposure is constant over time and argues that the time-varying exposure is driven by the shares of imports and exports in total production, cf. also the considerations contained in Levi (1994).

4.2 Augmentations of the regression approach

In addition to investigating different aspects of contemporaneous exchange rate exposure, such as various determinants and the time-variation of exposure, several authors have augmented the regression approach, either by including lagged exchange rate changes, cf. for example Amihud (1994), Bartov and Bodnar (1993) and Allayannis (1996), or by accounting for the correlation between exchange rates and interest rates over different horizons, that may influence the relation between stock market values and exchange rates, cf. Chow et al. (1997).

Whereas Amihud (1994) only finds weak evidence of a relation between exchange rate movements at time $t-1$ and stock market values at time t , Bartov and Bodnar (1993) and Allayannis (1996) find that lagged exchange rate changes are a significant, explanatory variable. According to these authors, this suggests that investors make systematic errors when characterizing the relation between firm value and exchange rates, possibly due to the complex set of issues involved in

evaluating this relation. It is only when information about the past performance of the firm is made available, that investors learn the full impact of exchange rate movements on firm value, suggesting another possible explanation for why previous research has met limited success in finding significant, contemporaneous exchange rate exposure for the stock market in the United States.

Applying the regression framework on various horizons, Chow et al. (1997) find no significant exchange rate exposure on short horizons, but find that a depreciation of the exchange rate is significantly correlated with an increase in stock market values on longer horizons. In order to explain these findings, Chow et al. (1997) argue that the relation between stock market values and exchange rates may be influenced by the correlation between exchange rates and interest rates. If exchange rate movements are correlated with changes in interest rates, it is important to account for the associated change in interest rates, in order to separate the relation between stock market values and exchange rates from the associated interest rate induced changes. Accounting for the correlation between exchange rates and interest rates, Chow et al. (1997) find that a current depreciation of the exchange rate is accompanied by a decrease in current and future interest rates. In isolation, the decrease in current and future interest rates should tend to increase stock market values on short and on longer horizons. However, Chow et al. (1997) find that a depreciation is correlated with a decrease in cash flows on short horizons and with an increase in cash flows on longer horizons. Therefore, the interest rate and cash flow effects are offsetting on short horizons and complementary over long horizons, explaining the observed pattern of exchange rate exposure over different horizons.

5 Exchange rate exposure in other countries than the United States

Although exchange rate exposure has been most extensively investigated for firms on the stock market in the United States, an increasing amount of research has been conducted for stock markets in other countries, including Japan (Bodnar and Gentry (1993), Chamberlain et al. (1997), Williamson (2001) and He and Ng (1998)), Canada (Bodnar and Gentry (1993)), Australia (Khoo (1994)), the United Kingdom (Donnelly and Sheehy (1996)), Finland (Talasmaki (1999)) and broad samples of countries, cf. Friberg and Nydahl (1999), among others.

Overall, these studies have had somewhat more success in documenting a significant, contemporaneous relation between stock market values and exchange rates, compared to the research conducted for firms in the United States. He and Ng (1998) find strong evidence of contemporaneous exchange rate exposure for multinationals in Japan, and Williamson (2001) finds that automotive firms in Japan are contemporaneously exposed to exchange rate movements. Furthermore, Bodnar and Gentry (1993) find that 35 percent of the Japanese industries included in their sample are significantly affected by exchange rate movements, whereas Chamberlain et al. (1997) only find weak evidence of significant exchange rate exposure for Japanese banking institutions. Evidence of significant, contemporaneous exchange rate exposure has also been documented for firms on the stock market in the United Kingdom, cf. Donnelly and Sheehy (1996), for companies in Finland, cf. Talasmaki (1999) and for firms on the stock market in Canada, cf. Bodnar and Gentry (1993). Khoo (1994), however, only finds weak evidence of exchange rate exposure for a sample of mining companies in Australia.

In line with the findings for firms in the United States, some of these studies have found that a higher ratio of foreign sales to total sales implies a stronger, contemporaneous correlation between a depreciation (appreciation) of the home currency and an increase in stock market values, cf. Bodnar and Gentry (1993),

Williamson (2001) and He and Ng (1998), and that a higher import ratio implies a more pronounced correlation between an appreciation of the home currency and an increase in stock market values, cf. Bodnar and Gentry (1993). Also in line with the findings for firms on the stock market in the United States, Williamson (2001) finds that foreign production decreases exposure and that the nature of competition is an important determinant of exposure for the sample of automotive firms in Japan. Furthermore, He and Ng (1998) find that the extent to which their sample of Japanese firms are exposed to currency fluctuations can be explained by factors that proxy for firms hedging incentives.

Also extending the evidence of time-varying exposure to stock markets in other countries than the United States, both Donnelly and Sheehy (1996) and Talasmaki (1999) find that exposure is different in various sub-periods, and relate the time-varying exchange rate exposure to changes in exchange rate regime. Finally, in the light of the findings for firms in the United States, several studies augment the regression approach by including lagged exchange rate movements, and find some evidence of a relation between exchange rate movements at time $t-1$ and stock market values at time t , cf. for example Donnelly and Sheehy (1996), He and Ng (1998) and Talasmaki (1999).

6 Chapter 2 and Chapter 3

The topics of chapter 2 and chapter 3 of the thesis are closely related to the empirical research reviewed in the previous sections. Therefore, it seems natural to summarize these chapters here.

6.1 Chapter 2: Exchange Rate Exposure in a Regime-Switching Model

This chapter contributes to the literature by incorporating the regression approach suggested by Adler and Dumas (1984) in a regime-switching model developed by Hamilton (1989,1990) and by applying this framework to investigate the contemporaneous relation between exchange rates and stock market values in Denmark. Incorporating the regression approach in a regime-switching model is motivated by preliminary evidence, indicating that the contemporaneous relation between stock market values and exchange rates in Denmark is unstable over time. However, rather than ex-ante dividing the sample into different sub-periods and applying the regression approach to these different sub-periods, cf. for example Williamson (2001), Donnelly and Sheehy (1996), Talasmaki (1999) and Jorion (1990), the view of this paper is that in the light of the numerous factors that potentially might influence exchange rate exposure and hence also induce exchange rate exposure to change over time, it is not possible ex-ante to know when the relation between stock market values and exchange rates might change. Therefore, instead of ex-ante dividing the sample period into different sub-periods and apply the regression approach to these different sub-periods, the approach followed in this paper is to let the data determine if and when possible changes in the contemporaneous relation between stock market values and exchange rates occur. By incorporating the regression approach, that has been widely applied in the empirical research on exchange rate exposure, in a two-state regime-switching model developed by Hamilton (1989,1990), this approach allows for the existence

of different regimes governing the contemporaneous relation between stock market values and exchange rates, without imposing any supposed a priori knowledge about the timing of possible changes in regime. Within this framework, the constant, the regression coefficient as well as the residual variance are allowed to depend on the regime, and what regime applies at any given point in time is governed by a stochastic state variable.

In the paper the approach is applied to monthly observations on the Danish stock market index and the trade-weighted exchange rate in the period from 1979 to 1999. The findings are, that there exist two persistent regimes governing the contemporaneous relation between stock prices and exchange rates. In the first short lived regime, there is no significant, contemporaneous relation between exchange rates and stock prices, whereas the relation is highly significant in the second and longer lasting regime, where a depreciation (appreciation) of the trade-weighted exchange rate is significantly correlated with a contemporaneous increase (decrease) in the stock market index.

6.2 Chapter 3: On the Dynamic Interaction Between Exchange Rates, Interest Rates and Stock Market Values

While chapter 2 in the thesis stays close to the tradition in the literature on exchange rate exposure by including exchange rates as the only independent variable, this chapter adds interest rates to data on exchange rates and stock market values and empirically investigates the dynamic interrelation between these variables by means of innovation accounting in a vector autoregressive model. The purpose of including interest rates alongside with exchange rates and stock market values is to account for the correlation between interest rates and exchange rates, that may influence the observed correlation between exchange rates and stock market values, cf. also Chow et al. (1997), and thereby provide a first step in the

direction of a more comprehensive picture of the relation between exchange rates and stock market values.

In particular, with some degree of correlation between exchange rates and interest rates, an observed relation between stock market values and exchange rate movements may either be induced by a change in exchange rates or by a change in interest rates. In the first case, an observed relation between stock market values and exchange rates may both reflect a direct exchange rate effect and an exchange rate associated interest rate effect, and in the second case, the direct interest rate effect may be accompanied by an interest rate associated exchange rate effect. In the context of a present value framework, allowing exchange rates and interest rates to be correlated and applying the interest rate as a proxy for the discount rate,

the value of a firm or a portfolio of firms, V , can be expressed as $V = \frac{1}{r(S)} \pi(S(r))$

, where r denotes the interest rate and π is profits net of taxes. The exchange rate, S , is defined so that an increase (decrease) is a depreciation (appreciation).

Differentiating partially with respect to the exchange rate, $\frac{dV}{dS} = -\frac{1}{r^2} \frac{dr}{dS} \pi + \frac{1}{r} \frac{d\pi}{dS}$, where

the first term on the right hand side is the exchange rate associated interest rate effect and the second term is the direct exchange rate effect. Consider the case

where a depreciation is correlated with a fall in interest rates, i.e. $\frac{dr}{dS} < 0$. In this

case, the exchange rate associated interest rate effect is positive. Then, if a depreciation is correlated with an increase in profits, $\frac{dV}{dS} > 0$. However, if a

depreciation is correlated with a decrease in profits, the sign of $\frac{dV}{dS}$ depends on

whether or not the direct exchange rate effect dominates the exchange rate associated interest rate effect. If the direct exchange rate effect dominates the

exchange rate associated interest rate effect, $\frac{dV}{dS} < 0$. However, when the exchange

rate associated interest rate effect dominates the direct exchange rate

effect, $\frac{dV}{dS} > 0$. Differentiating partially with respect to the interest rate,

$\frac{dV}{dr} = -\pi \frac{1}{r^2} + \frac{1}{r} \frac{d\pi}{dr} \frac{dS}{dr}$, where the first term on the right hand side is the direct

interest rate effect and the second term is the interest rate associated exchange rate

effect. Consider the case where an increase in the interest rate is correlated with

an appreciation, i.e. $\frac{dS}{dr} < 0$. Then, if an appreciation is correlated with a decrease

in profits, $\frac{dV}{dr} < 0$. If, on the other hand, an appreciation is correlated with an

increase in profits, the sign of $\frac{dV}{dr}$ depends on whether or not the direct interest

rate effect dominates the interest rate associated exchange rate effect. When the

direct interest rate effect dominates the interest rate associated exchange rate

effect, $\frac{dV}{dr} < 0$. However, when the interest rate associated exchange rate effect

dominates the direct interest rate effect, $\frac{dV}{dr} > 0$.

In the literature on exchange rate exposure only a few contributions, including Friberg and Nydahl (1999) and Chow et al. (1997), account for a potential correlation between interest rates and exchange rates, that may influence the observed correlation between exchange rates and stock market values. In the context of contemporaneous exchange rate exposure of national stock markets, Friberg and Nydahl (1999) find that inclusion of the interest rate as an explanatory variable in the regression framework suggested by Adler and Dumas (1984) tends to decrease the significance of the coefficient on the exchange rate, and argue that this probably reflects that the exchange rate and the interest rate are affected by the same domestic shocks, implying multicollinearity. Also within the framework of a regression model, Chow et al. (1997) find no significant exchange rate exposure on short horizons, but find that a depreciation of the exchange rate is significantly correlated with an increase in stock market values on longer horizons. Chow et al. (1997) argue, that these results are due to the offsetting respectively complementary effect of the correlation between exchange rates and interest rates on stock market values on different horizons, cf. also the discussion contained in section 4.

As opposed to the previous literature, however, this paper investigates the dynamic interactions between interest rates, exchange rates and stock market values by means of innovation accounting in a vector autoregressive model, rather than including the interest rate in a regression framework. This approach makes it possible to explicitly trace out the dynamic effect on stock market values induced by changes in exchange rates and interest rates, respectively, and to decompose the forecast error variance explained by innovations in each variable.

As for data on stock market values the paper applies monthly observations on both the stock market index and industrial production. Inclusion of industrial production in addition to the stock market index is motivated by the results in

Chow et al. (1997), who find that exchange rate movements have long run cash flow effects. However, since data on cash flows are not available and since industrial production should proxy for cash flows in a discounted cash flow framework, industrial production is applied as a proxy for aggregate cash flow, cf. also Choi et al. (1999). Including monthly observations on interest rates and the bilateral exchange rate vis-a-vis the United States alongside data on stock market values the main findings of the paper are, that an increase in the interest rate induces an appreciation of the exchange rate and that the correlation between interest rates and exchange rates results in a prolonged fall in the return on the stock market, approximated by the percentage, monthly change in the stock market index. Furthermore, a depreciation of the exchange rate does not induce a consistent change in the interest rate, but results in an increase in the return on the stock market, also for an extended period of time. Hence, by differentiating between exchange rate exposure induced by a change in the interest rate and by a change in the exchange rate, respectively, the chapter adds insight into the channels through which firms on the Danish stock market are exposed to exchange rate movements. In particular, the results show that firms on the Danish stock market are exposed to exchange rate movements, both through a direct exchange rate effect and through an interest rate associated exchange rate effect and that there appears to be no exchange rate associated interest rate effect. The absence of an exchange rate associated interest rate effect shows that movements in the exchange rate constitute an independent source of risk in relation to interest rates and the results should be viewed in light of the exchange rate regime in the period under consideration. With fixed exchange rates vis-a-vis Germany and floating exchange rates vis-a-vis the United States, a change in the interest rate is correlated with a change in the exchange rate vis-a-vis the United States, but a change in the exchange rate vis-a-vis the United States does not induce a change

in interest rates, allowing exchange rate movements to constitute an independent source of risk in relation to interest rates.

7 Pricing of exchange rate risk

While chapter 2 and chapter 3 in the thesis investigate different aspects of exchange rate exposure for the sample of firms listed on the Danish stock exchange, chapter 4 and chapter 5 investigate whether exchange rate movements are a priced factor on the Danish stock market, on a sector level and on a firm level, respectively.

In a frictionless world with complete markets, the Modigliani-Miller Theorem suggests that investors do not necessarily need to be compensated for the risk of exchange rate changes, if this source of risk can be diversified away. In such a frictionless world, shareholders can choose their own preferred risk profile given differences in exchange rate exposure of various sectors in the economy. On the other hand, the arbitrage pricing theory suggests that in an economy described by a number of pervasive factors, these factors might be priced in the sense that firms are required to pay investors for the risk of exchange rate changes, or - equally - investors will be willing to pay a price to avoid the risk associated with movements in exchange rates. Whether or not exchange rate risk is a priced factor is an important question, since it might have implications for the cost of capital. In particular, if exchange rate risk is priced, investors might be willing to pay a price to avoid the risk associated with movements in exchange rates, and firms might be able to decrease the cost of capital by hedging against exchange rate fluctuations.

In the literature several contributions have investigated whether or not exchange rate risk is priced on national stock markets, cf. among others Jorion (1991), Brown and Otsuki (1990) and Choi, Hiraki and Takezawa (1998). Jorion

(1991) finds that while the relation between stock returns and the value of the dollar differs systematically across industries in the United States, the empirical evidence does not suggest that exchange rate risk is priced on the stock market in the United States. Investigating the effect of macro-economic factors in the pricing of Japanese securities, Brown and Otsuki (1990) find that exchange rate risk is not priced in Japan, whereas Choi, Hiraki and Takezawa (1998) more recently have provided evidence that exchange rate risk is priced on the Japanese stock market.

In chapter 4, the pricing of exchange rate risk in Denmark is investigated on a sector level. In order to investigate whether exchange rate risk commands a risk premium on the Danish stock market, two factors are employed in the chapter, i.e. the market and innovations in the exchange rate orthogonal to the market. Within this framework, the issue is whether the premium on exchange rate changes is significant, i.e. whether changes in exchange rates are priced in a manner consistent with the APT-model. In the paper, time-series on excess returns are constructed by subtracting the risk-free rate of return from the monthly rate of change in the stock market index and from the monthly rate of change in the stock index for six different sectors, respectively, cf. also McElroy and Burmeister (1988) and Jorion (1991). With respect to innovations in the exchange rate, the paper applies two different measures, namely the monthly rate of change in the trade-weighted exchange rate and in the bilateral exchange rate vis-a-vis the United States. To avoid spurious pricing of the exchange rate factor because of possible correlation with a priced market, the exchange rate exposure orthogonal to the market is estimated for six different sectors in the economy. When innovations in the trade-weighted exchange rate orthogonal to the market are applied, the sign of exchange rate exposure varies across sectors but the exchange rate beta is not significant on a conventional level for any of the sectors. Applying the exchange rate vis-a-vis the United States, however, the exchange rate beta is

significant for shipping, where a depreciation (appreciation) of the exchange rate vis-a-vis the United States is correlated with an increase (decrease) in excess returns. Since the exchange rate beta is only significant on a sector level when the exchange rate vis-a-vis the United States is applied, the model is implemented with the market as the first factor and the exchange rate vis-a-vis the United States - purged of the influence of the market - as the second factor. Estimating the system as an iterated nonlinear seemingly unrelated regression model, the unconditional risk premium attached to exchange rate exposure is found to be positive and significant at a ten percent level. The positive and significant exchange rate price coefficient indicates that firms with a positive exchange rate exposure - i.e. firms for which a depreciation of Dkr. vis-a-vis the United States is correlated with an increase in returns - are expected to have a higher rate of return relative to firms that are not exposed to fluctuations in the exchange rate vis-a-vis the United States. In other words, a positive exchange rate exposure is a source of higher risk and higher expected return. These results are in contrast to the findings for the stock market in the United States, cf. Jorion (1991). Since the pricing of exchange rate risk on the Danish stock market implies that firms are required to pay investors for the risk of exchange rate changes, then - by the same token - investors will be willing to pay a price to avoid the risk associated with movements in exchange rates. Therefore, the results indicate that firms on the Danish stock market might be able to decrease the cost of capital by hedging against exchange rate movements.

Motivated by some evidence of significant exchange rate exposure for the shipping sector in Denmark, chapter 5 conducts a more comprehensive investigation of exchange rate exposure for firms within this sector and applies the same two factors as in chapter 4 in order to examine the pricing of exchange rate risk for firms in this sector of the economy. In the chapter exchange rate

exposure is found to be positive and significant for four of the firms in the sample. For these firms, a depreciation (appreciation) of the exchange rate vis-a-vis the United States is correlated with an increase (decrease) in excess returns. In this context it should be noted, that besides shipping, these firms are also involved in oil production and both freight rates and oil prices are usually set in US dollar. If the firms face prices that are exogenously determined in US dollar on the world market, then the firms cannot deliberately change their prices when the exchange rate fluctuates. Furthermore, if costs are relatively fixed in domestic currency, then exchange rate changes may have strong effects on the profitability of the firm and thereby on excess returns. However, it has not been possible to obtain any specific information on income and costs in US dollar for these firms. With respect to pricing of exchange rate risk, the exchange rate price coefficient is not significant when the framework contains nine firms within the sector, but the exchange rate price coefficient is significant at the ten percent level when the system contains five sectors and one of the firms which are found to be significantly exposed to exchange rate movements.

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Chapter 2

Exchange Rate Exposure in a Regime-Switching Model

BO DANØ¹

Abstract

This paper contributes to the literature on exchange rate exposure by incorporating the regression approach suggested by Adler and Dumas (1984) in a two state regime-switching model developed by Hamilton (1989, 1990) and by applying this framework to investigate the contemporaneous relation between stock market values and exchange rates in Denmark. Incorporating the regression approach in a regime-switching model is motivated by preliminary evidence of an unstable relation between stock market values and exchange rates, and the approach lets data and not supposed a priori knowledge determine when a possible change in regime takes place. The findings are that there exist two highly persistent regimes. In the first short lived regime, there is no significant, contemporaneous relation between exchange rates and stock market values, but in the second and longer lasting regime, the relation is highly significant. In particular, in the second regime, a depreciation (appreciation) of the trade-weighted exchange rate is significantly correlated with a contemporaneous increase (decrease) in the stock market index.

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1 Introduction

The high volatility of exchange rates as compared with other macroeconomic variables such as inflation and interest rates implies that exchange rate movements can be a major source of uncertainty for firms. Therefore, it is not surprising that the relation between exchange rates and the value of firms has attracted substantial attention in the academic literature. In the previous research, it has been common ground to estimate exchange rate exposure, broadly defined as the relation between exchange rates and the value of firms, by applying the regression approach suggested by Adler and Dumas (1984), cf. Jorion (1990), Bodnar and Gentry (1993), Amihud (1994), Levi (1994), Khoo (1994), Choi and Prasad (1995), Allayannis (1996), Donnelly and Sheehy (1996), Chamberlain et al. (1997), Chow et al. (1997), Allayannis (1997), Miller and Reuer (1998), He and Ng (1998), Talasmaki (1999), Friberg and Nydahl (1999), Allayannis and Ofek (2001), Williamson (2001), among others. This paper contributes to the literature by incorporating the regression approach in a regime-switching model developed by Hamilton (1989,1990), and the framework is subsequently applied to investigate exchange rate exposure in Denmark.

Incorporating the regression approach in a regime-switching model is motivated by preliminary evidence, indicating that the contemporaneous relation between stock market values and exchange rates in Denmark is unstable over time. However, rather than ex-ante dividing the sample into different sub-periods and apply the regression framework to these different sub-periods, as it is done in Williamson (2001), Donnelly and Sheehy (1996), Talasmaki (1999) and Jorion (1990), the view of this paper is, that in light of the numerous factors that potentially might influence exchange rate exposure and hence also induce exchange rate exposure to change over time, it is not possible ex-ante to know

exactly when the relation might change. Therefore, instead of ex-ante dividing the sample into different sub-periods and apply the regression analysis to these different periods, the approach followed in this paper is to let the data determine if and when possible changes in the relation occur. By incorporating the regression approach, that has been widely applied in the research on exchange rate exposure, in a two-state markov regime-switching model developed by Hamilton (1989,1990), this allows for the existence of different regimes governing the contemporaneous relation, without imposing any supposed a priori knowledge about the timing of possible changes in regime. Within this framework, the constant, the regression coefficient as well as the residual variance, are allowed to depend on the regime, and what regime applies at any given point in time is governed by a stochastic state variable.

The paper is organized as follows: Section 2 contains a short review of the foundation for measuring exposure as a regression coefficient, developed by Adler and Dumas (1984), and recent applications. In section 3 the method is incorporated in the regime-switching model, and the contemporaneous relation between the stock market index and the trade-weighted exchange rate in Denmark is investigated within this framework. Section 4 contains the concluding remarks.

2 The Regression Approach to Exchange Rate Exposure

In their landmark paper, Adler and Dumas (1984) define exchange rate exposure as the sensitivity of the value of firms to exchange rate movements and show that exposure can be measured as the regression coefficient of the value of the firm on exchange rates across different states of nature. To illustrate this, consider the

random dollar price, P , of a risky asset on a given future date². The number of states of nature, K , is finite with known probabilities and in a given state, k , the outcome P_k is associated with a vector of state variables, $S_k = \{S_1, \dots, S_n\}_k$, including exchange rates. Exposure is then defined as the current expectation across future states of nature, of the partial sensitivity of P to the i 'th state variable, S_i , when the effects of all other variables are held constant, i.e. as $E\{\partial P / \partial S_i\} = E\{\partial E[g(P)|S] / \partial S_i\} = \text{Cov}[g(P), S_i] / \text{Var}(S_i) = E[g'(P)] b_{pi} = b_{pi}$, where b_{pi} is the regression coefficient of P on S_i in the bivariate case and $g(P) = P$. This definition of exposure amounts to a decomposition of the probability distribution of a risky asset's domestic currency price at a future instance into two parts: One that is correlated with the exchange rate, and a second that is independent of the exchange rate. Since stock market values and exchange rates are determined jointly, it is simply a statistical decomposition and does not imply a causal relationship between exchange rates and stock markets.

For firms on the stock market in the United States, previous research have applied the regression framework to investigate the significance of exposure and various factors that influence the extent to which firms are exposed to exchange rate movements. In general, this research has met limited success in documenting significant, contemporaneous exchange rate exposure, cf. Jorion (1990), Amihud (1994), Allayannis (1996), Choi and Prasad (1995), Bodnar and Gentry (1993), Miller and Reuer (1998), Chamberlain et al (1997) and Williamson (2001), among others. As for the factors that influence exchange rate exposure, several studies have found that a higher ratio of foreign sales to total sales implies a stronger, contemporaneous correlation between a depreciation (appreciation) of the dollar and an increase (decrease) in stock market values, cf. among others Jorion (1990),

²This paragraph follows the appendix in Adler and Dumas (1984).

Bodnar and Gentry (1993), Amihud (1994), Allayannis (1997), Williamson (2001) and Allayannis and Ofek (2001). Bodnar and Gentry (1993) and Allayannis (1997) show that a higher import ratio implies a more pronounced correlation between an appreciation of the dollar and an increase in stock market values. In addition, Williamson (2001) finds that foreign production decreases exposure, consistent with the idea that an exporter can decrease the sensitivity of its cash flow to exchange rate movements by having cost denominated in the local currency, cf. also Miller and Reuer (1998). Furthermore, Williamson (2001) shows that the nature of competition is an important determinant of exchange rate exposure, as pointed out on a theoretical level by Marston (1996). Allayannis and Ofek (2001) find that the use of derivatives significantly reduces exposure and their evidence also supports the hypothesis that firms use derivatives and foreign debt as a hedge against exchange rate movements, providing one possible explanation for the previous research's limited success in documenting significant, contemporaneous exposure for firms on the stock market in the United States.

For firms on stock markets in other countries than the United States, previous research have met somewhat more success in finding significant exposure, cf. Bodnar and Gentry (1993), Chamberlain et al. (1997), Williamson (2001), He and Ng (1998), Khoo (1994), Donnelly and Sheehy (1996), Talasmaki (1999) and Friberg and Nydahl (1999), among others. In line with the findings for firms in the United States, Bodnar and Gentry (1993), Williamson (2001) and He and Ng (1998) find that a higher ratio of foreign sales to total sales implies a stronger, contemporaneous correlation between a depreciation (appreciation) of the home currency and an increase in stock market values, and Bodnar and Gentry (1993) also show that a higher import ratio implies a more pronounced correlation between an appreciation of the home currency and an increase in stock market

values. Also in line with the findings for firms on the stock market in the United States, Williamson (2001) finds that foreign production decreases exposure and that the nature of competition is an important determinant of exposure for the sample of automotive firms in Japan. He and Ng (1998) show that the extent to which their sample of Japanese firms are exposed to currency fluctuations can be explained by factors that proxy for firms hedging incentives.

Within the literature, several contributions have conjectured that since the numerous factors that affect exchange rate exposure are not constant through time, exchange rate exposure may be time-varying, cf. among others Jorion (1990), Levi (1994), Amihud (1994), Allayannis (1997), Williamson (2001), Donnelly and Sheehy (1996) and Talasmaki (1999). In particular, based on an ex-ante division of the sample period into different sub-periods, both Jorion (1990) and Amihud (1994) find that the sign as well as the significance of exposure are different in the various sub-periods, and Williamson (2001) relates evidence of time-varying exposure in the automotive industry to changes in the competitive structure of this industry. Allayannis (1997) is able to reject the hypothesis that exchange rate exposure is constant over time and argue that the time-varying exposure is driven by the shares of imports and exports in total production, cf. also the considerations contained in Levi (1994). Extending the evidence of time-varying exposure to stock markets in other countries than the United States, both Donnelly and Sheehy (1996) and Talasmaki (1999) find that exposure is different in various sub-periods, and relate the evidence of time-varying exchange rate exposure to changes in exchange rate regime.

In the next section, the possibility of time-varying exposure is investigated for Denmark. However, rather than ex-ante dividing the sample into different sub-periods, the possibility of different regimes governing the contemporaneous

relation between stock market values and exchange rates is examined by incorporating the regression framework in a two state regime-switching model.

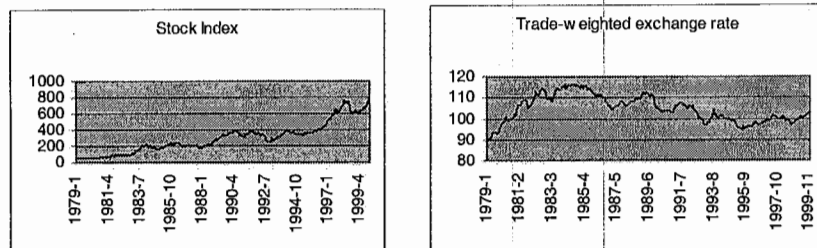
3 Exchange Rate Exposure in a Regime-Switching Model

The data applied in the regime-switching model consist of monthly observations on the stock market index and the trade-weighted exchange rate, both measured in nominal terms. The choice of monthly frequency is in line with a large part of the previous, empirical research conducted for other countries, cf. for example Jorion (1990), Bodnar and Gentry (1993), Khoo (1994), Choi and Prasad (1995), Donnelly and Sheehy (1996), Allayannis (1997), Miller and Reuer (1998), He and Ng (1998), Friberg and Nydahl (1999), Allayannis and Ofek (2001) and Williamson (2001), and nominal variables are used in Bodnar and Gentry (1993), Khoo (1994), Chamberlain et al. (1997), Friberg and Nydahl (1999) and Allayannis and Ofek (2001), among others. The stock market index is measured ultimo month and includes all firms listed on the Danish stock exchange³. The stock market index does not include dividends, so changes in the index reflect capital gains or losses. This is in line with Bodnar and Gentry (1993), who measure market return as the dividend exclusive return for the equally weighted market portfolio. Following Jorion (1990), Bodnar and Gentry (1993), Bartov and Bodnar (1994), Ibrahimi et al. (1995), Donnelly and Sheehy (1996) and Chow et al. (1997), among others, the trade-weighted exchange rate index is applied, also in nominal terms and measured ultimo month. The trade-weighted exchange rate is defined such that an increase (decrease) is a depreciation (appreciation).

³The weights in the stock market index are altered continuously, when firms enter or exit the stock market or when new emissions occur.

The variables in levels, covering the period from primo 1979 to ultimo 1999, are shown in Figure 1⁴:

Figure 1: Variables in levels



Note: Data on the stock index and the trade-weighted exchange rate are provided by the National Bank of Denmark.

According to an Augmented Dicky-Fuller test, the percentage, monthly change in the stock index and the percentage, monthly change in the trade-weighted exchange rate are both stationary variables, cf. Table 1.

⁴The choice of period is based on availability of data: Time series on the trade-weighted exchange rate measured ultimo month do not exist before 1979.

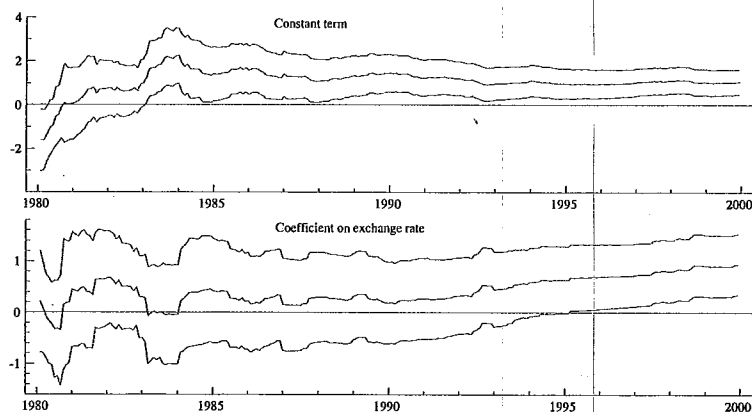
Table 1: Stationarity Test (ADF)

Variable	Constant and trend 5% critical value: -3.45 10% critical value: -3.15	Constant 5% critical value: -2.89 10% critical value: -2.58
Stock index	-0.89 [0]	0.98 [0]
Percentage change in stock index	-5.58* [13]	-5.45* [13]
Trade-weighted exchange rate	-2.73 [0]	-1.33 [0]
Percentage change in trade-weighted exchange rate	-14.45* [0]	-14.46* [0]

Note: The columns contain the test statistics from a regression with a constant plus a trend and with a constant. The regressions include 13 lags to begin with, and the lag length is chosen by sequentially applying an F-test until the joint hypothesis $\beta_{s,1} = \dots = \beta_{s,L} = 0$ is rejected for some L. Numbers in square brackets denote the number of lags in the final regression and the critical values are from Hamilton (1994). * denotes rejection of the null hypothesis of non-stationarity at a 5 percent level.

Since $E\{\partial E[g(P)|S]/\partial S\} = \text{Cov}[g(P), S]/\text{Var}(S) = E[g'(P)]b_{p|s} = b_{p|s}$, where $b_{p|s}$ is the regression coefficient of P on S in the bivariate case, exchange rate exposure can be measured as the regression coefficient of stock market values on the contemporaneous value of exchange rates, cf. Adler and Dumas (1984). Preliminary evidence on the stability of the relation between stock market values and exchange rates can be obtained by estimating the coefficients of the ordinary least squares recursively, i.e. by recursive least squares. Figure 2 shows the recursive point estimates of the constant term and of the coefficient on the trade-weighted exchange rate, including 95 percent confidence intervals, in a simple regression of the percentage, monthly change in the stock market index on the contemporaneous value of the percentage, monthly change in the trade-weighted exchange rate.

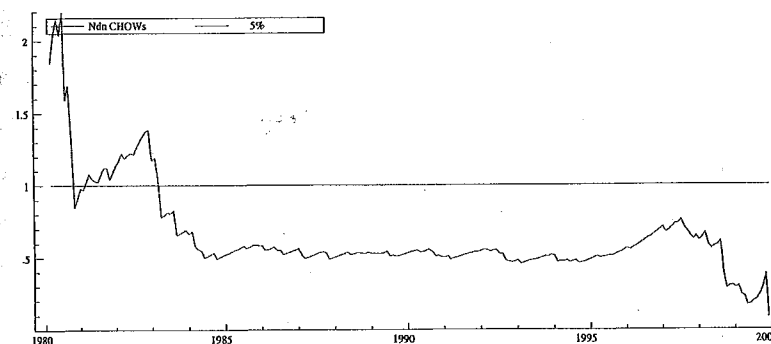
Figure 2: Recursive Parameter Estimates in One-Regime model



Note: The figure shows $\hat{\beta}_i \pm 2SE(\hat{\beta}_i)$ for each coefficient ($i = 0, 1$). In the recursive least squares estimation, the equation is fitted to an initial sample of $M-1$ points, then to samples of $M, M+1, \dots$ up to T observations so the statistics are recalculated adding observations one at a time, cf. Hendry (1995). The recursive least squares estimation has been implemented in PcGive.

As it appears from Figure 2, both coefficients are unstable over time. Furthermore, based on the break-point Chow test, the null of stability of the model is rejected at a five percent level, cf. Figure 3.

Figure 3: Break-point Chow test for stability



Note: Break-point Chow test for stability of the simple Adler and Dumas (1984) regression approach to the contemporaneous relation between stock markets and exchange rates. In the graph, each point gives the value of the Chow F-test for that date against the final period scaled by its critical value, so the forecast horizon is decreasing from left to right. Values above the vertical line indicate rejection of the null of stability at a five percent level. The test has been implemented in PcGive.

In light of the apparent instability of the parameters, a model that allows for more than one regime is estimated. To this end, the Markov-switching model developed by Hamilton (1989,1990) is used. This model has been applied in many different contexts, cf. Engel and Hamilton (1990), Hamilton and Lin (1996), Whitelaw (2000) and Campbell, Lo and Mackinlay (1997), among others, and has several appealing features. First and foremost, possible changes in regime are not determined by a priori inspection but rather by the interaction between data. Therefore, the approach has the advantage of letting data and not supposed a priori knowledge determine when a possible change in regime takes place. Second, what regime applies at a given point in time is governed by a stochastic state variable, that is assumed to be independent of the residual term across all periods of time. In other words, the state-process is assumed to evolve purely exogenously to the dynamics of the variables. Third, since the state variable can be estimated by

Hamilton's (1989) filtering process, we can identify the regime in which the process was in at any given point in time with some degree of confidence.

In order to incorporate the Adler and Dumas (1984) approach in the Markov-switching framework, it is necessary to introduce some notation⁵. Let SI_t denote the percentage, monthly change in the stock index at time t and ER_t the percentage, monthly change in the trade-weighted exchange rate, also at time t . Furthermore, let s_t denote the regime at date t , $s_t = 1, 2$ and α the vector of parameters characterizing the conditional density, which is assumed to be normal. The (2×1) vector of the conditional density of the percentage, monthly change in the stock index, η_t , is given by:

$$(1) \eta_t = \begin{bmatrix} f(SI_t | s_t = 1; \alpha) = \frac{1}{\sqrt{2\pi}\sigma_1} \exp \left[\frac{-(SI_t - \beta_0(1) - \beta_1(1)ER_t)^2}{2\sigma_1^2} \right] \\ f(SI_t | s_t = 2; \alpha) = \frac{1}{\sqrt{2\pi}\sigma_2} \exp \left[\frac{-(SI_t - \beta_0(2) - \beta_1(2)ER_t)^2}{2\sigma_2^2} \right] \end{bmatrix}$$

The state-variable, s_t , follows a *first-order* Markov process with transition probabilities expressed as:

$$(2) P\{s_t = j | s_{t-1} = i\} = \begin{bmatrix} p_{11} & 1-p_{22} \\ 1-p_{11} & p_{22} \end{bmatrix}$$

where p_{ij} is the probability of being in regime j in period t , conditional on having been in regime i in period $t-1$. The probability that the unobserved regime j was responsible for producing the observation at date t is given by:

⁵A general version of the model can be found in Hamilton (1994).

$$P\{s_t = j | SI_t, ER_t\} = \frac{\Pi_j \frac{1}{\sqrt{2\pi}\sigma_j} \exp \left[\frac{-(SI_t - \beta_0(j) - \beta_1(j)ER_t)^2}{2\sigma_j^2} \right]}{\frac{\Pi_1}{\sqrt{2\pi}\sigma_1} \exp \left[\frac{-(SI_t - \beta_0(1) - \beta_1(1)ER_t)^2}{2\sigma_1^2} \right] + \frac{\Pi_2}{\sqrt{2\pi}\sigma_2} \exp \left[\frac{-(SI_t - \beta_0(2) - \beta_1(2)ER_t)^2}{2\sigma_2^2} \right]}$$

where θ denotes the vector of population parameters and Π_j , $j=(1,2)$, is the unconditional probability that s_t takes on the value j .

A regime is defined as a sub-period in which the coefficient on the explanatory variables - including the constant term - are constant. A regime-shift takes place, when the regression framework for exchange rate exposure changes, either because of a change in the explanatory power of the exchange rate or the constant term or because of a change in the part of the volatility in stock market values that is not explained by the model. The regime-switching model can be estimated by Maximum Likelihood, cf. Hamilton (1994). The Maximum Likelihood estimation is implemented with the state probabilities of the initial observation given by the ergodic probabilities, calculated as the unconditional probabilities. The unconditional probability for regime 1 is given by $(1 - p_{22}) / (2 - p_{11} - p_{22})$; and the unconditional probability for regime 2 is given by $(1 - p_{11}) / (2 - p_{11} - p_{22})$; cf. Hamilton (1994).

The computations are done using the BFGS-algorithm in GAUSS. Using different starting values for the algorithm, there is more than one local maximum and the results in Table 2 apply to the local maximum with the highest likelihood. This choice is consistent with Kiefer (1978) who in the context of the mixed-distribution model - where a global maximum does not exist - shows that there is

a bounded local maximum of the likelihood function that has the usual maximum likelihood properties, i.e. consistency and asymptotically efficiency.

Table 2: Maximum Likelihood Estimates of the Regime-Switching Model

		<i>Regime 1</i>	<i>Regime 2</i>
Constant term.	β_0	-1.1486 (-1.7166)	1.2503* (4.1978)
Exchange rate	β_1	-0.1186 (-0.2861)	1.2337* (3.8319)
Variance	σ^2	4.1916 (2.5934)	20.6789 (10.7945)
Transition probability	p_{ii}	0.9790 (23.5916)	0.9958 (210.2388)
Ergodic probability		0.1644	0.8356
Log-likelihood		-728.7930	

Note: Asymptotic t-ratios are shown in parentheses. * denotes significance at the 5 percent level.

In Table 2, the coefficient on the percentage monthly change in the trade-weighted exchange rate (β_1) is negative in regime 1 and positive in regime 2. This implies, that a depreciation of the trade-weighted exchange rate is correlated with a contemporaneous fall in stock market values in regime 1 but with an increase in stock market values in regime 2. However, the relation between stock market values and exchange rates is only significant in regime 2. These results suggest that there are two regime-dependent underlying models for the contemporaneous relation: One in which the contemporaneous relation is insignificant and one in which there is a significant, contemporaneous relation.

According to the estimated transition probabilities in Table 2, both regimes are rather persistent, with the probability of continuing in a given regime being 97.90 to 99.58 percent. The state variable s_t is unobservable, but from the estimated transition probabilities, it is possible to draw probabilistic inference about the regime at any given point in time. This inference is expressed by the filtered state probability, defined as the probability of being in, say, state 1 at any

given point in time, conditional on all information on observables, i.e. stock market values and exchange rates, up to and including time t . The estimated filtered state probabilities, expressed as the probability of being in regime 1, are shown in figure 4.

Figure 4: Filtered probabilities for regime 1

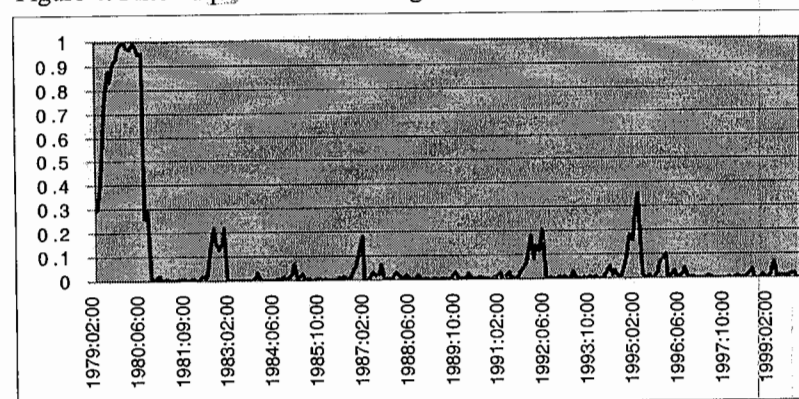


Figure 4 gives a rather clear inference about the state variable. Using 50 percent as the dividing line, the results suggest that the sample period can be divided into two distinct sub-periods: The short period from 1979:4 to 1980:6, where the contemporaneous relation between stock market values and exchange rates is governed by regime 1 and the much longer period from 1980:7 and onward, where the relation is governed by regime 2.

Compared with previous research for other countries, the finding that a depreciation (appreciation) of the trade-weighted exchange rate is significantly correlated with a contemporaneous increase (decrease) in the stock market index for the majority of the period under consideration is in contrast with the limited success in documenting significant, contemporaneous exchange rate exposure in the United States, cf. Jorion (1990), Amihud (1994), Allayannis (1996), Choi and

Prasad (1995), Bodnar and Gentry (1993), Miller and Reuer (1998), Chamberlain et al. (1997) and Williamson (2001). However, the result is more in line with the significant exposure found in other countries than the United States, cf. Bodnar and Gentry (1993), Chamberlain et al. (1997), Williamson (2001), He and Ng (1998), Khoo (1994), Donnelly and Sheehy (1996), Talasmaki (1999) and Friberg and Nydahl (1999), among others.

Some insight into the possible determinants of the significant correlation between a depreciation (appreciation) of the trade-weighted exchange rate and an increase (decrease) in the stock market index for the majority of the period can be obtained by investigating the contemporaneous relation between stock prices and the most important, bilateral exchange rates in the trade-weighted exchange rate. Following Schnabel (1989), who extends the approach suggested by Adler and Dumas (1984) to the case with many currencies, the stock market index is regressed on the four most important, bilateral exchange rates in the trade-weighted exchange rate, i.e. the exchange rate vis-a-vis Germany, the United Kingdom, Sweden and the United States⁶. The bilateral exchange rates are also defined such that an increase (decrease) is a depreciation (appreciation). According to an Augmented Dicky-Fuller test, all four bilateral exchange rates are stationary in the percentage, monthly change, cf. Table 1A in the appendix. In the period governed by regime 2, the exchange rate vis-a-vis the United Kingdom and vis-a-vis the United States, respectively, are both significantly correlated with the stock market index on a conventional level, whereas the other bilateral exchange rates are insignificant.

⁶Each of these bilateral exchange rates enters into the weight of the trade-weighted exchange rate with a share on or above 10 percent: The exchange rate vis-a-vis Germany with a share of around 25 percent, the exchange rate vis-a-vis Sweden with a share of about 12 percent and the exchange rate vis-a-vis the United Kingdom and the United States each with a share of around 10 percent. So taken together, these bilateral exchange rates account for about 60 percent of the weights in the trade-weighted exchange rate.

In particular, conducting a general-to-specific approach in the period governed by regime 2, i.e. starting with a regression including all four bilateral exchange rates and successively removing the insignificant exchange rates, the result is: $SI = 1.2^{**} + 0.2USD^* + 0.3GBP^*$, where SI, USD and GBP is the percentage, monthly change in the stock index, the exchange rate vis-a-vis the United States and vis-a-vis the United Kingdom, respectively, and * (**) denotes significance at a 5 (1) percent level. These results imply that a one percent depreciation of the exchange rate vis-a-vis the United States is correlated with a contemporaneous increase in the stock index of 0.2 percentage points, and a depreciation of the exchange rate vis-a-vis the United Kingdom is correlated with an increase in the stock index of 0.3 percentage points. Since a depreciation of the home currency benefits the export-sector and hurts the import-sector, cf. also the models contained in Levi (1994), Marston (1996), Bodnar et al. (1998) and Allayannis and Ihrig (2000), one possible explanation for the significant regime prevailing in the majority of the period under consideration might be linked to the net trade balance vis-a-vis the United States and the United Kingdom. Specifically, taken together, Denmark has had a rather consistent trade surplus vis-a-vis the United Kingdom and the United States since the middle of 1983, which might contribute to explain the relation found in regime 2. In order to obtain some information about the exchange rate exposure of individual firms listed on the Danish stock exchange, the percentage, monthly change in stock prices for a number of the larger firms is regressed on the percentage, monthly change in the trade-weighted exchange rate, the exchange rate vis-a-vis the United States and the exchange rate vis-a-vis the United Kingdom, respectively. The regression results are shown in Table 3.

Table 3: Exchange rate exposure for individual stocks

Firm	Trade-weighted exchange rate (percentage change)		Exchange rate vis-a-vis the United States (percentage change)		Exchange rate vis-a-vis the United Kingdom (percentage change)	
	β_0	β_1	β_0	β_1	β_0	β_1
Carlsberg	1.5*(3.0)	0.9 (1.7)	1.5*(2.9)	0.1 (0.9)	1.5*(3.0)	0.2 (1.1)
Top Danmark	0.7 (1.1)	1.1 (1.6)	0.6 (1.0)	0.3 (1.7)	0.6 (1.0)	0.1 (0.5)
Danisco	1.5*(3.4)	0.5 (1.0)	1.6*(3.4)	0.0 (0.0)	1.6*(3.4)	0.4*(2.3)
Den Danske Bank	1.4*(2.8)	0.5 (1.0)	1.4*(2.8)	0.2 (1.2)	1.4*(2.9)	0.1 (0.4)
ISS	2.0*(3.1)	1.0 (1.4)	1.9*(3.1)	0.3 (1.6)	2.0*(3.1)	0.3 (1.2)
Novo	1.9*(3.4)	2.7*(4.5)	1.8*(3.2)	0.9*(5.0)	2.0*(3.5)	1.0*(4.3)
D/S 1912	1.8*(3.3)	1.8*(3.0)	1.7*(3.2)	0.6*(3.6)	1.9*(3.3)	0.2 (0.9)

Note: The table shows the estimated coefficients from the linear regression in which the percentage, monthly change in stock prices for the particular firm is regressed on a constant (β_0) and on the percentage, monthly change in the trade-weighted exchange rate, the exchange rate vis-a-vis the United States and the exchange rate vis-a-vis the United Kingdom, respectively. β_1 is the estimated coefficient on the percentage, monthly change in the exchange rate under consideration and hence corresponds to the exchange rate exposure coefficient. The regressions are estimated on data covering the period governed by regime 2, i.e. from 1980:7 to 1999:12, except for Top Danmark and ISS, where the first available data on stock prices are in 1985:11 and 1982:1, respectively. Data on all variables are in nominal terms and are measured ultimo month. Stock prices for the individual firms are obtained from Datastream. t-values are shown in parenthesis and * denotes significance at the 5 percent level.

As it appears from Table 3, all exchange rate exposure coefficients (β_1) are positive, which implies that a depreciation of each of the three exchange rates is correlated with an increase in stock market values for all the firms under consideration. The exchange rate exposure coefficient is significant for Novo and D/S 1912, when the trade-weighted exchange rate is applied, significant for the same two firms when the exchange rate vis-a-vis the United States is applied and significant for Danisco and Novo, when the exchange rate vis-a-vis the United Kingdom is applied. Since the results presented in Table 3 only covers a proportion of the firms entering in the stock market index, care should be taken in trying to draw general conclusions on the basis of these results. However, it

should be noted that the sign of the exchange rate exposure coefficient for the firms included in the sample is in line with the result obtained in the regime-switching model for the majority of the period under consideration.

Conducting a similar general-to-specific approach in the period governed by regime 1 shows that non of the four bilateral exchange rates are significant on a conventional level. In this period, Denmark has had a rather consistent trade deficit vis-a-vis the United Kingdom and the United States, taken together. However, on average, the trade deficit in the period governed by regime 1 has not been as large as the trade surplus in the period governed by regime 2, which might contribute to explain the difference in significance between the two regimes.

Finally, although the sum of the net export to the United States and the United Kingdom has been rather consistently negative in the period governed by regime 1 and rather consistently positive from the middle of 1983 and onward, the regime-shift takes place before the sum of the net export becomes consistently positive, indicating that while the trade balance vis-a-vis the United States and the United Kingdom might contribute to explain the results, the trade balance cannot fully account for the exact timing of the change in regime. As documented by previous research conducted for other countries, a number of other factors, such as the use of derivatives or the existence of foreign production might also influence exposure, cf. Williamson (2001), Allayannis and Ofek (2001) and He and Ng (1998). Therefore, the extent to which these factors change over time could also influence the exact timing of the regime-shift⁷. In addition, as noted by Friberg and Nydahl (1999), limited exchange rate pass-through would imply that the effect

⁷It would have been interesting to explore these possibilities further, by examining how the use of derivatives or the existence of foreign production affect the extent to which firms are exposed to exchange rate movements. However, since data on imports and exports for particular firms and the use of hedging devices are not available, it has not been possible to conduct such an analysis.

of a depreciation will tend to be stronger for exporting firms than for importing or import-competing firms. Hence, the existence of limited exchange rate pass-through could potentially also contribute to explain that the change in regime takes place before net export becomes consistently positive.

4 Concluding remarks

This paper has investigated the contemporaneous exchange rate exposure for firms listed on the Danish stock exchange by means of recursive least squares and by incorporating the regression approach suggested by Adler and Dumas (1984) in a regime-switching model developed by Hamilton (1989,1990). Applying monthly data on the stock market index and on the trade-weighted exchange rate, the recursive parameter estimates indicate that the contemporaneous relation between exchange rates and stock market values is unstable over time. Rather than dividing the sample period into different sub-periods and applying the regression approach to these different sub-periods, cf. for example Williamson (2001), Donnelly and Sheehy (1996), Talasmaki (1999) and Jorion (1990), the regression approach to exchange rate exposure suggested by Adler and Dumas (1984) is subsequently incorporated in a regime-switching model developed by Hamilton (1989,1990), allowing the data to determine if and when possible changes in the contemporaneous relation between stock market values and exchange rates occur. Within this framework, the regime applying at any given point in time is governed by a stochastic state variable, that is assumed to be independent of the residual term across all periods of time. Since the state variable can be estimated by Hamilton's filtering process, it is possible to identify the regime in which the process was in at any given point in time with some degree of confidence. A regime is defined as a sub-period in which the coefficient on the explanatory variables - including the constant term - is constant, and a regime-shift takes place,

when the regression framework for exchange rate exposure changes, either because of a change in the explanatory power of the exchange rate or the constant term or because of a change in the part of the volatility in stock market values that is not explained by the model.

The model is estimated by Maximum Likelihood, implemented with the state probabilities of the initial observation given by the ergodic probabilities, and the local maximum with the highest likelihood gives rise to one short lived regime, where the contemporaneous relation between exchange rates and stock market values is insignificant and a second much longer lasting regime, where the relation is significant. In the significant regime, a depreciation (appreciation) of the trade-weighted exchange rate is correlated with a contemporaneous increase (decrease) in the stock market index. Furthermore, probabilistic inference based on the estimated transition probabilities shows that the contemporaneous relation between stock market values and the trade-weighted exchange rate is governed by the significant regime from the beginning of the eighties and onward. Compared with previous research for other countries, this finding is in contrast with the limited success in documenting significant, contemporaneous exposure in the United States, and more in line with the significant exposure documented in other countries. One possible explanation for the significant regime prevailing in the majority of the period under consideration might be related to the fact that the sum of the net export vis-a-vis the United States and the United Kingdom has been rather consistently positive since the middle of the eighties. In the period governed by regime 1, however, Denmark has had a fairly consistent trade deficit vis-a-vis these two countries.

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Appendix

Table 1A: Stationarity test (ADF)

Variable	Constant and trend 5% critical value: -3.45 10% critical value: -3.15	Constant 5% critical value: -2.89 10% critical value: -2.58
Exchange rate vis-a-vis Germany	-1.63 [13]	-2.96* [13]
Percentage change in exchange rate vis-a-vis Germany	-13.75* [0]	-13.38* [0]
Exchange rate vis-a-vis the United Kingdom	-1.78 [0]	-1.40 [0]
Percentage change in exchange rate vis-a-vis the United Kingdom	-14.00* [0]	-14.01* [0]
Exchange rate vis-a-vis Sweden	-3.21 [13]	-1.27 [13]
Percentage change in exchange rate vis-a-vis Sweden	-13.46* [0]	-13.48* [0]
Exchange rate vis-a-vis the United States	-2.86 [13]	-2.40 [13]
Percentage change in exchange rate vis-a-vis the United States	-14.63* [0]	-14.66* [0]

Note: The columns contain the test statistics from a regression with a constant plus a trend and with a constant. The regressions include 13 lags to begin with, and the lag length is chosen by sequentially applying an F-test until the joint hypothesis $\beta_{s,1} = \dots = \beta_{s,L} = 0$ is rejected for some L. Numbers in square brackets denote the number of lags in the final regression and the critical values are from Hamilton (1994). * denotes rejection of the null hypothesis of non-stationarity at a 5 percent level.

Chapter 3

On the Dynamic Interaction Between Exchange Rates, Interest Rates and Stock Market Values

BO DANØ¹

Abstract

This paper investigates the dynamic interaction between exchange rates, interest rates and stock market values in Denmark, by means of innovation accounting in a vector autoregressive (VAR) model. By applying this approach, it is possible to trace out the dynamic effect on stock market values induced by changes in exchange rates and interest rates, respectively, and to decompose the forecast error variance explained by innovations in each variable. The main findings are, that an increase in interest rates induce an appreciation of the exchange rate, and that the correlation between interest rates and exchange rates result in a fall in the return on the stock market, approximated by the percentage, monthly change in the stock market index, for a lengthy period of time. A depreciation does not induce a consistent change in the interest rate but results in an increase in the return on the stock market, also for a prolonged period.

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1 Introduction

In this paper, the dynamic interaction between exchange rates, interest rates and stock market values in Denmark is investigated by means of innovation accounting in a VAR model. The purpose of including interest rates alongside with exchange rates and stock market values is to account for the correlation between interest rates and exchange rates that may influence the observed correlation between exchange rates and stock market values, cf. also Chow et al. (1997), and thereby provide a first step in the direction of a more comprehensive picture of the relation between exchange rates and stock market values.

In particular, with some degree of correlation between exchange rates and interest rates, an observed relation between stock market values and exchange rate movements may either be induced by a change in exchange rates or by a change in interest rates. In the first case, an observed relation between stock market values and exchange rates may both reflect a direct exchange rate effect and an exchange rate associated interest rate effect, and in the second case, the direct interest rate effect may be accompanied by an interest rate associated exchange rate effect. In the context of a present value framework, allowing exchange rates and interest rates to be correlated and applying the interest rate as a proxy for the discount rate, the value of a firm or a portfolio of firms, V , can be expressed as $V = \frac{1}{r(S)} \pi(S(r))$, where r denotes the interest rate and π is profits net of taxes. The exchange rate, S , is defined so that an increase (decrease) is a depreciation (appreciation).

Differentiating partially with respect to the exchange rate, $\frac{dV}{dS} = -\frac{1}{r^2} \frac{dr}{dS} \pi + \frac{1}{r} \frac{d\pi}{dS}$, where

the first term on the right hand side is the exchange rate associated interest rate effect and the second term is the direct exchange rate effect. Consider the case

where a depreciation is correlated with a fall in interest rates, i.e. $\frac{dr}{dS} < 0$. In this case, the exchange rate associated interest rate effect is positive. Then, if a depreciation is correlated with an increase in profits, $\frac{d\pi}{dS} > 0$. However, if a depreciation is correlated with a decrease in profits, the sign of $\frac{dV}{dS}$ depends on

whether or not the direct exchange rate effect dominates the exchange rate associated interest rate effect. If the direct exchange rate effect dominates the exchange rate associated interest rate effect, $\frac{dV}{dS} < 0$. However, when the exchange rate associated interest rate effect dominates the direct exchange rate effect, $\frac{dV}{dS} > 0$. Differentiating partially with respect to the interest rate,

$$\frac{dV}{dr} = -\pi \frac{1}{r^2} + \frac{1}{r} \frac{d\pi}{dr} \frac{dS}{dr}$$

where the first term on the right hand side is the direct

interest rate effect and the second term is the interest rate associated exchange rate effect. Consider the case where an increase in the interest rate is correlated with an appreciation, i.e. $\frac{dS}{dr} < 0$. Then, if an appreciation is correlated with a decrease

in profits, $\frac{d\pi}{dr} < 0$. If, on the other hand, an appreciation is correlated with an increase in profits, the sign of $\frac{dV}{dr}$ depends on whether or not the direct interest

rate effect dominates the interest rate associated exchange rate effect. When the direct interest rate effect dominates the interest rate associated exchange rate

effect, $\frac{dV}{dr} < 0$. However, when the interest rate associated exchange rate effect dominates the direct interest rate effect, $\frac{dV}{dr} > 0$.

In the literature on exchange rate exposure, only a few contributions, including Friberg and Nydahl (1999) and Chow et al. (1997), account for a potential correlation between interest rates and exchange rates that may influence the observed correlation between exchange rates and stock market values. In the context of contemporaneous exchange rate exposure of national stock markets, Friberg and Nydahl (1999) find that inclusion of the interest rate as an explanatory variable in the regression framework suggested by Adler and Dumas (1984) tends to decrease the significance of the coefficient on the exchange rate, and argue that this probably reflects that the exchange rate and the interest rate are affected by the same domestic shocks, implying multicollinearity. Also within the framework of a regression model, Chow et al. (1997) find no significant exchange rate exposure on short horizons, but find that a depreciation of the exchange rate is significantly correlated with an increase in stock market values on longer horizons. Chow et al. (1997) argue, that these results are due to the offsetting respectively complementary effect of the correlation between exchange rates and interest rates on stock market values on different horizons.

Compared with the previous literature, this paper investigates the dynamic interaction between interest rates, exchange rates and stock market values by means of innovation accounting in a VAR model, rather than by including interest rates in a regression framework. This approach makes it possible to explicitly trace out the dynamic effect on stock market values induced by changes in exchange rates and interest rates, respectively, and to decompose the forecast error variance explained by innovations in each variable.

The paper is organized as follows: Section 2 reviews innovation accounting

in a VAR model and the data are described in section 3. Section 4 presents the results from innovation accounting in the VAR framework, and section 5 contains the concluding remarks.

2 Innovation accounting in a VAR model

Innovation accounting in a VAR model works with unrestricted, reduced forms, treating all variables as endogenous and imposing no restrictions based on a rigorous theoretical framework². Let Z_t denote an $(m \times 1)$ vector of endogenous variables in period t . Z_t is a zero-mean covariance stationary process having the vector moving average (VMA) representation

$$(1) \quad Z_t = B(L)e_t = \sum_{s=0}^{\infty} B(s)e_{t-s}$$

The $(m \times 1)$ vector e_t is the innovation in Z_t , and it is a vector generalization of white noise. It is a one-step-ahead least squares forecasting error in predicting Z_t as a function of past values of Z_t , i.e. $e_t = Z_t - E[Z_t | Z_{t-s}, s \geq 1]$. The (i,j) th component of $B(s)$, $b_{ij}(s)$, is the dynamic response of each endogenous variable to a shock, after s periods.

In order to decompose the forecast error variances in the variables into components attributable to each innovation, a transformation of e_t is performed. Let $\text{var}(e_t) = \Sigma$ and let G be a matrix such that $\Sigma^{-1} = G'G$. Now define a transformed innovation, u_t , where $u_t = Ge_t$. Then $\text{var}(u_t) = \text{var}(Ge_t) = G\Sigma G' = G(G'G)^{-1}G' = GG^{-1}(G')^{-1}G' = I_m$, where I_m is an identity matrix of rank m . The innovations, e_t , are transformed by applying the Choleski Decomposition, imposing $(m^2-m)/2$ restrictions. This decomposition places a triangular structure on the G -matrix and implies that innovations in some variables do not have a contemporaneous impact

²The discussion of innovation accounting in a VAR framework contained in this section is very similar to the discussion in Lee (1992). A textbook exposition is contained in for example Enders (1995).

on some of the other variables. Depending on the contemporaneous correlation between the innovations, the results might be sensitive to the ordering of the variables³. Z_t can be expressed as

$$(2) \quad Z_t = \sum_{s=0}^{\infty} B(s)e_{t-s} = \sum_{s=0}^{\infty} B(s)G^{-1}u_{t-s} = \sum_{s=0}^{\infty} C(s)u_{t-s}$$

where $C(s) \equiv B(s)G^{-1}$. The coefficients of $C(s)$ represent responses to innovations in particular variables. In order to derive the forecast error variance, note that from the view-point of time 0, the expected value of all future innovations is equal to zero. Hence, the t -step-ahead forecast of Z_t based on $Z_0, Z_{-1}, Z_{-2}, \dots$, is given by

$$(3) \quad E[Z_t | Z_0, Z_{-1}, Z_{-2}, \dots] = \sum_{s=t}^{\infty} C(s)u_{t-s}$$

cf. also Lee (1992)⁴. The t -step ahead forecast error, w_t , is given by

$$(4) \quad w_t = Z_t - E[Z_t | Z_0, Z_{-1}, Z_{-2}, \dots] = \sum_{s=0}^{t-1} C(s)u_{t-s}$$

where u_t is the innovation in period t ⁵. The t -step ahead forecast error variance can then be expressed as

³The sensitivity of the results to different orderings is investigated in the appendix.

⁴For example, for $t=1$, $E[Z_1 | Z_0, Z_{-1}, Z_{-2}, \dots] = E[C(0)u_1 + C(1)u_0 + C(2)u_{-1} + \dots | Z_0, Z_{-1}, \dots] = C(1)u_0 + C(2)u_{-1} + \dots$, which is the right hand side of equation (3), for $t=1$. $C(0)$ is the response to innovations in the same period as the innovation occurred, $C(1)$ is the response to innovations one period after the innovation occurred, etc. In other words, $C(1)u_0$ is the effect in period 1 of the innovation in period 0 (u_0), $C(2)u_{-1}$ is the effect in period 1 of the innovation in period -1 (u_{-1}), etc. Since the expected value of u_t is equal to zero as of time 0, $C(0)u_t$ does not enter on the right-hand side of equation (3). To summarize, for $t=1$, $C(t+1)$ in equation (3) represents the response in period 1 to an innovation in period -1. For $t=2$, $C(t+1)$ in equation (3) represents the response in period 2 to an innovation in period -1, etc.

⁵For example, with $t=1$, the right hand side of equation (4) is $C(0)u_1$, where u_1 is the innovation in period 1. With $t=2$, the right hand side of equation (4) is $C(0)u_2 + C(1)u_1$, where u_2 is the innovation in period 2 and u_1 is the innovation in period 1. As of time 0, both u_1 and u_2 are expected to be equal to zero, and hence enter in the forecast error for period 2.

$$(5) \quad E[w_t w_t'] = E[(\sum_{s=0}^{t-1} C(s)u_{t-s})(\sum_{s=0}^{t-1} u_{t-s}' C(s)')]]$$

When u_{t-s} and u'_{t-s} have the same dates, $E(u_{t-s}u'_{t-s}) = I_m$, $E(u_{t-s}u'_{t-j}) = 0 \forall s \neq j$.

Therefore, the t -step ahead forecast error variance can be expressed as

$$(6) \quad E(w_t w_t') = \sum_{s=0}^{t-1} C(s)C(s)'$$

Based on shares of diagonal elements of $E(w_t w_t')$, the percentage of the t -step ahead forecast error variance in z_i , accounted for by innovations in variable z_j ($FEVD_{ij}$) is

$$(7) \quad FEVD_{ij} = \frac{\sum_{s=0}^{t-1} c_{ij}(s)^2}{\sum_{j=1}^m \sum_{s=0}^{t-1} c_{ij}(s)^2} \times 100$$

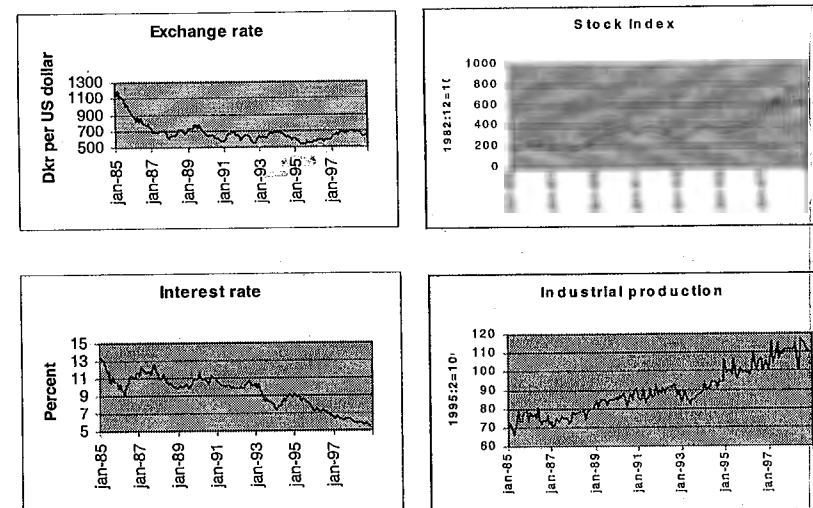
3 The Data

The data applied in the empirical analysis consist of monthly observations on the stock market index, industrial production, the exchange rate vis-a-vis the United States and interest rates. The sample period is from January 1985 to December 1998, and all variables are in nominal terms⁶. The stock market index, the exchange rate and the interest rate is measured ultimo month. As for data on stock market values, industrial production is included alongside with the stock market index in order to allow for the existence of cash flow effects of exchange rate

⁶The sample period starts in 1985 since this was the period in which it was possible to obtain the most consistent time series data on industrial production. In particular, in 1986 the Danish Statistical Bureau decided to alter the statistics on industrial production, cf. the Monthly Review of Statistics (1990): Supplement. The revised index is only available from January 1985.

movements, cf. the results in Chow et al. (1997)⁷. The measure applied for industrial production is the monthly turnover in the industrial sector, in nominal terms. The exchange rate is measured as the Danish (Dkr) price of US dollar. Thus an increase (decrease) in the exchange rate represents a depreciation (appreciation) of the Dkr vis-a-vis the US dollar⁸. The interest rate is an average figure including government bonds and a selection of property bonds, where the average is obtained by weighting according to the market value of the circulated amount. This interest rate is available ultimo month in the entire sample period. Figure 1 shows the variables in levels.

Figure 1: Variables in levels



Note: Interest rates and exchange rates are provided by the National Bank of Denmark. The stock market index and industrial production, i.e. the monthly turnover in the industrial sector, are provided by the Danish Statistical Bureau.

⁷There does not exist monthly data on cash flows for firms listed on the Danish stock exchange. However, in a discounted cash flow framework, industrial production should proxy for aggregate cash flows, cf. also Choi et al. (1999). Even though the empirical analysis cannot separate directly between exchange rate effects through interest rates versus industrial production, inclusion of industrial production allows for the existence of cash flow effects. It should be noted, that when innovation accounting is conducted in a VAR model that only includes exchange rates, interest rates and the stock market index, qualitative similar results are obtained with respect to the dynamic interaction between these three variables.

⁸One of the reasons why the exchange rate vis-a-vis the United States is applied, is that Denmark has had a floating exchange rate regime vis-a-vis the United States. In the context of this chapter, this allows for a more clear distinction between exchange rate and interest rate induced effects, as compared with a situation where both floating and fixed exchange rates are involved, as is the case with the trade-weighted exchange rate. Furthermore, the exchange rate vis-a-vis the United States is one of the more important exchange rates in the trade-weighted exchange rate, in the sense that it enters into the weight of the trade-weighted exchange rate with a share of around 10 percent.

In Figure 1, the stock market index and industrial production trended upward, the interest rate followed a downward-sloping trend, and the exchange rate appreciated until 1995, depreciating slightly hereafter. Information on the properties of the variables is obtained by investigating the series stationarity properties. To test the stationarity of the series, the augmented Dickey-Fuller (ADF) test is applied, which tests the significance of the parameter η in the regression

$$(8) \quad \Delta X_t = \eta X_{t-1} + \beta_1 \Delta X_{t-1} + \dots + \beta_s \Delta X_{t-s} + u_t, \quad u_t \sim \text{IN}(0, \sigma_u^2)$$

The null hypothesis is that X_t is a random walk, and the alternative is that the series is stationary, which requires a significant, negative test statistics. Since the underlying time series data are in levels, the stationarity of the level of the interest rate and of the log-level of industrial production, the stock market index and the exchange rate, respectively, are examined first. The test statistics depend on whether the null is a random walk with drift or a random walk with drift and a deterministic trend, and the results are reported in Table 1. The top rows of Table 1 show that the null hypothesis that each of the four variables are non-stationary in levels cannot be rejected at a 5 percent level. However, when the regression includes a constant and a trend, industrial production might be considered trend-stationary at a 10 percent level. Furthermore, when the regression only includes a constant, the null hypothesis of non-stationarity is rejected at a 10 percent level for the exchange rate series.

Next, the stationarity of the difference of the interest rate and of the log-difference of industrial production, the stock market index and the exchange rate, respectively, are investigated. The results from the augmented Dickey Fuller test are shown in the four bottom rows of Table 1. For the difference of the interest rate and log-difference of the stock market index and industrial production, the null hypothesis of non-stationarity is unambiguously rejected. When the regression only includes a constant, the null hypothesis of non-stationarity is rejected for the exchange rate. When the exchange rate equation includes a constant and a trend, the null hypothesis of non-stationarity cannot be rejected at a 5 percent level. Based on the results in Table 1, the difference of the interest rate and the log-difference of the exchange rate, industrial production and the stock market index are considered to be stationary time series.

Table 1: Stationarity Test (ADF)

Variable	Constant and trend 5% critical value:-3.45 10% critical value:-3.15	Constant 5% critical value:-2.89 10% critical value:-2.58
Stock index (log-level)	-1.72 [0]	-0.14 [0]
Interest rate (level)	-3.12 [12]	0.35 [12]
Industrial production (log-level)	-3.15 [11]	-1.78 [11]
Exchange rate (log-level)	-2.58 [0]	-2.73 [0]
Stock index (log-difference)	-3.84* [13]	-3.77* [13]
Interest rate (difference)	-4.99* [11]	-4.73* [11]
Industrial production (log-difference)	-5.20* [9]	-5.16* [9]
Exchange rate (log-difference)	-3.31 [13]	-3.25* [13]

Note: The columns contain the test statistics from a regression with a constant plus a trend and with a constant. The regressions include 13 lags to begin with, and the lag length is chosen by sequentially applying an F-test until the joint hypothesis $\beta_{s,1} = \dots = \beta_{s,L} = 0$ is rejected for some L. There are no signs of autocorrelation in the residuals. Numbers in square brackets denote number of lags in the final regression. The critical values are from Hamilton (1994). * denotes rejection of the null hypothesis of non-stationarity at a 5 percent level.

4 Empirical results

A number of studies, cf. for example Jorion (1990) and Bartov and Bodnar (1994), focus exclusively on the bilateral relation between exchange rates and stock market values. Before turning the attention to innovation accounting in a VAR model, the importance of monthly variations in the exchange rate - and each of the other variables - for the monthly variations in the stock market return, approximated by the log-difference of the stock market index, are investigated by testing the joint significance of the parameters β_1 to β_{p+1} in the regression

$$(9) \quad z_t = \alpha_0 + \alpha_1 z_{t-1} + \dots + \alpha_p z_{t-p} + \beta_1 x_t + \dots + \beta_{p+1} x_{t-p} + e_t$$

The null hypothesis is that $\beta_1 = \dots = \beta_{p+1} = 0$. Table 2 shows the results when the regressions include the contemporaneous value and three lags of the variable in question.

Table 2: Likelihood Ratio Test

	Exchange rate (log-difference)	Interest rate (difference)	Industrial production (log-difference)
Stock index (log-difference)	$\chi^2(4) = 9.2^*$ (p = 0.06)	$\chi^2(4) = 61.03^{**}$ (p = 0.00)	$\chi^2(4) = 1.92$ (p = 0.75)

Note: The null hypothesis is tested with the Likelihood Ratio test statistics $(T-c)(\log|\Sigma_r| - \log|\Sigma_u|)$, where $|\Sigma_r|$ and $|\Sigma_u|$ is the determinant of the variance-covariance matrix of the restricted and unrestricted system, T is number of observations and c is number of parameters in the unrestricted system. The test statistics are asymptotic χ^2 -distributed with degrees of freedom equal to the number of restrictions. With the contemporaneous value and three lags of the variable in question in each regression, the number of restrictions is equal to 4. * (**) denote rejection of the null hypothesis at a 10 (5) percent level.

As it appears from Table 2, both the log-difference of the exchange rate and the difference of the interest rate contribute significantly to explain the return on the stock market, approximated by the log-difference of the stock market index. In contrast, Jorion (1990) is unable to document a significant, bilateral relation between exchange rates and stock returns for a selected sample of firms in the United States. Hence, the finding is consistent with the assumption that firms are more exposed to exchange rates movements in more open economies, cf. Bodnar and Gentry (1993) and Friberg and Nydahl (1999). When the test is applied to the relation between the log-difference of the stock market index and the log-difference of industrial production, the null hypothesis cannot be rejected.

Information on the dynamic interactions between the four variables is obtained by investigating how a variable responds to shocks in other variables and

the extent to which a variable helps explain other variables. In order to determine the appropriate lag length in the VAR model, a test of system reduction is conducted and the Akaike, Schwartz and Hannan-Quinn criteria is implemented in a system containing the interest rate in levels and log-levels of industrial production, the exchange rate and the stock market index. The results from these different lag length test, implemented in a system containing from 5 to 1 lag of each of these variables, together with the value of the log-likelihood function, are shown in Table 3.

Table 3: Lag length test

VAR lag length	Test of system reduction	Log-likelihood	Akaike	Schwartz	Hannan-Quinn
1	F(16,461)=1.40 [0.13]	1846.9	-22.66	-22.04	-22.26
2	F(16,449)=2.05* [0.01]	1858.77	-22.81	-21.68	-22.09
3	F(16,437)=1.27 [0.21]	1876.27	-23.02	-21.4	-21.98
4	F(16,425)=0.68 [0.81]	1887.6	-23.16	-21.04	-21.8
5	X	1893.89	-22.24	-20.61	-21.56

Note: A maximum lag length of 5 gives 74 degrees of freedom: With 168 observations, 4 variables and 5 lags in each equation, 94 degrees of freedom are lost, i.e. 80 variables contained in the system, 4 constants and 10 parameters within the variance-covariance matrix, leaving 74 degrees of freedom. The test of system reduction is an F-approximation for the Likelihood Ratio test suggested by Rao (1973), cf. Doornik and Hendry (1996). * denotes rejection of system reduction.

The results in Table 3 show that the test of system reduction accepts a reduction from 5 to 4 and from 4 to 3 lags, but the hypothesis of reducing the system further is rejected. The Schwartz and Hannan-Quinn criteria suggests a system with one lag and the Akaike criteria is minimized in the system with four lags. The results from multivariate and univariate diagnostic test show that the system including 4 lags of each of the variables in log levels is fairly well specified, cf. Table 4.

Table 4: Multivariate and univariate diagnostic test

	Multivariate	Univariate			
		Industrial production	Interest rate	Exchange rate	Stock index
Vector error autocorrelation of order 2	F(32,499)=0.3 [0.29]	F(2,144)=0.5 [0.64]	F(2,144)=0.3 [0.77]	F(2,144)=1.98 [0.14]	F(2,144)=0.08 [0.92]
Vector error autocorrelation of order 4	F(64,499)=1.2 [0.13]	F(4,142)=0.99 [0.42]	F(4,142)=1.1 [0.34]	F(4,142)=1.7 [0.16]	F(4,142)=0.1 [0.98]
Vector error autocorrelation of order 6	F(96,473)=1.2 [0.15]	F(6,140)=0.7 [0.66]	F(6,140)=1.2 [0.31]	F(6,140)=1.8 [0.11]	F(6,140)=0.4 [0.90]
Vector heteroscedasticity (squares)	F(320,1022)=1.1 [0.25]	F(32,113)=1.4 [0.13]	F(32,113)=1.5 [0.07]	F(32,113)=0.8 [0.83]	F(32,113)=1.3 [0.15]*
Vector normality	$\chi^2(8)=26.31$ [0.00]**	$\chi^2(2)=20.6$ [0.00]**	$\chi^2(2)=2.0$ [0.37]	$\chi^2(2)=1.5$ [0.47]	$\chi^2(2)=1.2$ [0.55]
ARCH(1)	X	F(1,144)=0.4 [0.51]	F(1,144)=1.2 [0.27]	F(1,144)=0.6 [0.43]	F(1,144)=0.6 [0.5]

Note: The table shows the results from multivariate and univariate diagnostic tests in a system with a constant and four lags of each of the variables in log levels. The multivariate test of vector error autocorrelation is an F-approximation based on a comparison of the likelihoods of the restricted and unrestricted system. The multivariate test of vector heteroscedasticity is based on a regression of the endogenous variables on all squares of the regressors. The univariate test of error autocorrelation is the Lagrange Multiplier test and the univariate test of ARCH is based on a regression of squared residuals on a constant and lagged, squared residuals. * (**) denote misspecification at a 5 percent (1 percent) level.

Based on the lag length test in combination with the multivariate and univariate diagnostics test, the system in the levels of the interest rate and the log-levels of industrial production, the exchange rate and the stock market index is implemented with a constant and 4 lags.

In the light of the results obtained in the augmented Dickey-Fuller test, which shows that the null hypothesis of non-stationary cannot be rejected at a 5 percent level for each of the variables in levels, the issue of cointegration needs to be addressed. In this context, testing for cointegration using the procedure suggested by Engle and Granger (1987) has several important limitations. First, this approach is not necessarily invariant to the choice of variables selected for normalization. Second, with four variables, there may be more than one

cointegrating vector, and the method proposed by Engle and Granger (1987) has no systematic procedure for the separate estimation of multiple cointegrating vectors. Third, the two-step procedure implies that any errors introduced in the first step is carried into the second step. In light of these limitations, the issue of cointegration is addressed by applying the Johansen (1988) maximum likelihood estimators, which circumvent the use of two-step estimators and can estimate and test for the presence of multiple cointegrating vectors. The statistics from the trace test of the cointegrating rank in a system containing four lags of each of the variables in levels and a constant, together with the eigenvalues and the 90 and 95 percent critical values, are shown in Table 5.

Table 5: Cointegrating Rank

Rank (r)	0	1	2	3
Eigenvalue	0.15	0.07	0.03	0.00
Trace test	44.28*	17.35	4.79	0.20
90 percent critical value	43.84	26.70	13.31	2.71
95 percent critical value	47.21	29.38	15.34	3.84

Note: For each value of r, the Trace test tests the null hypothesis, $H_0: \text{rank} \leq r$ against the alternative $H_A: \text{rank} > r$. The null hypothesis is rejected if the trace statistics are sufficiently large. Critical values are from Table 15.3 in Johansen (1996). * denotes rejection of the null hypothesis at a 10 percent level.

The results in Table 5 show that it is possible to reject the null hypothesis of no cointegrating vectors ($r \leq 0$) and accept the alternative of one or more cointegrating vectors at a 10 percent level, but not at a 5 percent level of significance. Next, the trace statistics are used to test the null of $r \leq 1$ against the alternative of two or more cointegrating vectors. The results show that the null hypothesis cannot be rejected on neither a 5 nor a 10 percent level of significance. Based on these results, it is concluded that there is at most one cointegrating vector in the system. However,

the results in favour of the existence of one cointegrating vector are not strong, in the sense that the null hypothesis of no cointegrating vectors is rejected in favour of one or more cointegrating vectors on a 10 percent level, but not on a 5 percent level of significance.

The Maximum Likelihood estimates of the normalized cointegrating vector are reported in Table 6.

Table 6: Estimated Cointegrating Vector (Normalized)

Industrial production (IP)	Interest rate (r)	Exchange rate (S)	Stock index (SI)
-7.32	-0.28	-4.52	1.00

The estimated cointegrating vector implies that $SI = 7.32IP + 0.28r + 4.52S$. To the extent that industrial production is a proxy for aggregate cash flows, a relation expressing that an increase in industrial production is related to an increase in the stock index does not seem implausible, and this result is not inconsistent with the findings for other countries, cf. for example Ansotegui et al. (2002). An increase in the interest rate is related to an increase in the stock index, which is not in accordance with its role as a discount rate. Furthermore, an increase in the exchange rate (a depreciation) is related to an increase in the stock index. Since a depreciation of the home currency benefits the export-sector and hurts the import-sector, a relation between a depreciation and an increase in the stock index should possibly be interpreted in the light of the rather persistent trade surplus vis-a-vis the United States in the period under consideration.

In the light of the problems with the economic interpretation of the unrestricted, cointegrating vector, in particular the sign of the coefficient for the interest rate, various identifying, zero restrictions are imposed. Specifically, the hypothesis $\beta = H\phi$ is tested, where β is a 4×1 vector, H is a known $4 \times k$ matrix and

ϕ is a $k \times 1$ vector of unknown parameters. With no strong economic priors concerning the kind of restriction to impose, different zero restrictions are tried. Table 7 shows the restrictions placed on the β -vector, the estimated β -vector, the χ^2 test statistics and p values for each case.

Table 7: Test of restrictions on the cointegrating vector

	Industrial production (IP)	Interest rate (r)	Exchange rate (S)	Stock index (SI)	$\chi^2(v)$	p val.
R ₁	0.00 [--]	0.13 [0.15]	9.98 [2.05]	1.00 [--]	4.08 (1)	0.04*
R ₂	-3.77 [1.22]	0.00 [--]	-6.17 [1.25]	1.00 [--]	3.45 (1)	0.06
R ₃	-5.21 [1.04]	-0.16 [0.08]	0.00 [--]	1.00 [--]	13.99 (1)	0.00*
R ₄	0.98 [0.36]	0.06 [0.03]	1.00 [--]	0.00 [--]	1.57 (1)	0.21
R ₅	0.00 [--]	0.00 [--]	23.81 [4.64]	1.00 [--]	4.25 (2)	0.12
R ₆	-2.99 [0.34]	0.00 [--]	0.00 [--]	1.00 [--]	16.98 (2)	0.00*
R ₇	1.00 [--]	0.07 [0.01]	0.00 [--]	0.00 [--]	17.37 (2)	0.00*
R ₈	0.00 [--]	-0.004 [0.01]	1.00 [--]	0.00 [--]	4.46 (2)	0.11
R ₉	0.00 [--]	0.19 [0.05]	0.00 [--]	1.00 [--]	22.31 (2)	0.00*
R ₁₀	0.17 [0.18]	0.00 [--]	1.00 [--]	0.00 [--]	3.94 (2)	0.14
R ₁₁	0.00 [--]	0.00 [--]	0.00 [--]	1.00 [--]	24.62 (3)	0.00*
R ₁₂	1.00 [--]	0.00 [--]	0.00 [--]	0.00 [--]	23.28 (3)	0.00*
R ₁₃	0.00 [--]	1.00 [--]	0.00 [--]	0.00 [--]	24.73 (3)	0.00*
R ₁₄	0.00 [--]	0.00 [--]	1.00 [--]	0.00 [--]	4.54 (3)	0.21

Note: The asymptotic distribution of the maximum likelihood estimates for β is a mixed Gaussian distribution, implying that the Likelihood Ratio tests for restrictions on β are asymptotically χ^2 distributed, cf. Johansen (1996). Numbers in square brackets denote standard errors and numbers in brackets denote degrees of freedom. The tests are implemented in CATS. * denotes rejection of the null hypothesis.

To determine whether or not each variable enters in the cointegrating space, the insignificance of IP, r , S and SI within the equilibrium relationship were tested in R_1 to R_4 . To determine whether combinations of the variables are insignificant, two zero restrictions were imposed in R_5 to R_{10} . Finally, with three zero restrictions placed on the cointegrating space, R_{11} to R_{14} can be interpreted as a multivariate test for stationarity of each of the variables, given the assumption that the rank is equal to one. On the basis of the figures presented in Table 7, the restrictions imposed in R_2 , R_4 , R_5 , R_8 , R_{10} and R_{14} , cannot be rejected. Therefore, these cases are discussed in turn.

The estimated relation in the case where the restriction is placed on the interest rate (R_2) implies that $SI = 3.77IP + 6.17S$, and both coefficients are significant. Hence, it indicates a significant relation between an increase in industrial production and an increase in the stock index. Also, an increase in the exchange rate (a depreciation) is significantly related to an increase in the stock index. This seems to be a plausible economic relation, cf. the discussion contained above. However, the result is not robust to the choice of normalization. In particular, normalizing with respect to the exchange rate instead of the stock index implies that $S = 0.16SI - 0.61IP$, where the standard error for the coefficient on SI is 0.17, and the standard error for the coefficient on IP is 0.46, implying that both coefficients are insignificant.

In R_4 , where the zero restriction is imposed on the stock index, the estimated relation implies that $S = -0.98IP - 0.06r$. Hence, in this case there is a relation between an increase in industrial production and a decrease in the exchange rate (an appreciation). Furthermore, an increase in the interest rate is related to a decrease in the exchange rate (an appreciation). This does not seem to be inconsistent with standard, open economy macroeconomic theory. However, while the coefficient on industrial production is significant, the coefficient on the

interest rate is only marginally significant. In addition, when the interest rate is excluded from the equation, industrial production turns out to be insignificant in the relation, cf. R_{10} .

Restricting both industrial production and the interest rate (R_5) implies a significant relation between an increase in the exchange rate (a depreciation) and a decrease in the stock index, i.e. $SI = -23.81S$. This result does not seem to be coherent with the rather persistent trade surplus vis-a-vis the United States in the period under consideration. Furthermore, the result is not robust to the choice of normalization. Normalizing with respect to the exchange rate instead of the stock index gives rise to the relation $S = -0.04SI$, where the standard error for the coefficient on SI is 0.07, implying that the coefficient is insignificant.

When restrictions are placed on both industrial production and the stock index (R_8), an increase in the interest rate is related to an increase in the exchange rate (a depreciation), i.e. $S = 0.004r$. However, the coefficient on the interest rate is not significant. In R_{10} , there is a relation between an increase in industrial production and a decrease in the exchange rate (an appreciation), i.e. $S = -0.17IP$, but the coefficient on industrial production is not significant. Finally, in the multivariate test for stationarity of each of the variables, given the assumption that the rank is equal to one, the exchange rate turns out to be stationary, cf. R_{14} .

On an overall level, the test of restrictions conducted in the above shows, that while a number of zero restrictions can not be rejected, the resulting relations are either not significant (R_8 and R_{10}), not robust to the choice of normalization (R_2 and R_5) or only marginally significant with respect to one of the variables (R_4), and when this variable is excluded from the relation, the other variable is insignificant. Therefore, none of these relations are imposed on the system. On the basis of the result in R_{14} , the model could possibly be specified in the level of the exchange rate alongside with the other variables in first differences. On the other hand, this

result is obtained under the assumption that the cointegrating rank is equal to one, which can only be accepted on a 10 percent level and not on a 5 percent level, cf. Table 5. Furthermore, the results obtained in the augmented Dickey-Fuller test show that the exchange rate is non-stationary both on a 5 percent level and on a 10 percent level when the regression includes a constant and a trend and non-stationary on a 5 percent level, when the regression only includes a constant, cf. Table 1. Therefore, innovation accounting is conducted in a VAR model containing the first differences of each of the four variables together with a constant and without imposing any cointegrating relations. The impulse responses generated from this system are traced out in Figure 2.

Figure 2: Impulse response functions

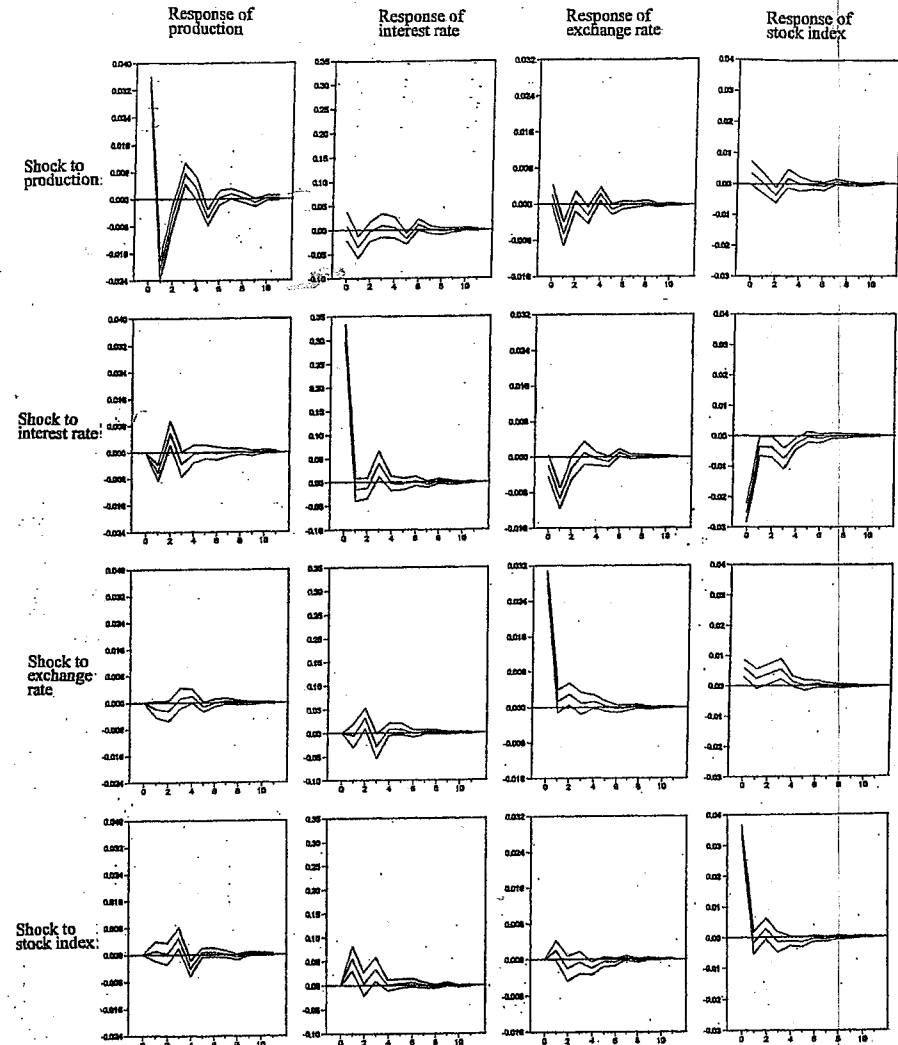


Figure 2 shows the response of the difference of the interest rate and of the log difference of the exchange rate, industrial production and the stock market index to an impulse in each of these time series, with standard error bands. This implies that it is the response of the return on the stock market, approximated by the log-difference of the stock market index, that is traced out in Figure 2. Since all the time series are stationary, the variables do not have a long memory, in the sense that innovations in the series do not tend to persist. This is in accordance with Figure 2, where all variables have returned to baseline after about one year following the initial impulse.

In Figure 2, an increase in the interest rate induces an appreciation of the exchange rate - i.e. a fall in the exchange rate - and a fall in the return on the stock market. In other words, there are both a direct interest rate effect and an interest rate associated exchange rate effect. The response of the return on the stock market is strongly negative in the first couple of months, but the effect remains negative for a more extended period of time. These findings also show, that it is important to account for an appreciation associated with an increase in interest rates. Only including interest rates will overestimate the proportion of the fall in stock returns that is caused by a rise in interest rates, since part of this fall might be explained by the associated appreciation of the exchange rate. Furthermore, Figure 2 shows that a depreciation of the exchange rate - i.e. an increase in the exchange rate - results in an increase in the return on the stock market. The response of the return on the stock market to a depreciation is strongest in the first month and in the third and fourth month. In Figure 2, a depreciation does not induce a consistent positive or negative response in the interest rate. This implies that the prolonged increase in the return on the stock market is induced by the depreciation and not by an induced change in the interest rate, i.e. there is no

exchange rate associated interest rate effect⁹.

That an increase in the interest rate induce an appreciation of the exchange rate and that these interrelationships are correlated with an increase in the return on the stock market are in line with findings on long horizons for stock returns in the United States, cf. Chow, Lee and Solt (1997). However, as opposed to these findings for the United States, an increase in interest rates and the associated appreciation of the exchange rate is correlated with a fall in the return on the Danish stock market on all horizons under consideration. Moreover, the absence of an exchange rate associated interest rate effect shows that movements in the exchange rate constitute an independent source of risk in relation to interest rates, and the results should be viewed in light of the exchange rate regime in the period under consideration. With fixed exchange rates vis-a-vis Germany and floating exchange rates vis-a-vis the United States, a change in the interest rate is correlated with a change in the exchange rate vis-a-vis the United States, but a change in the exchange rate vis-a-vis the United States does not induce a change in interest rates, allowing exchange rate movements to constitute an independent source of risk in relation to interest rates. Furthermore, one possible explanation for the finding that a depreciation induces an increase in the return on the stock market is, that Denmark has had a positive net export vis-a-vis the United States in most of the period under consideration. However, the trade balance vis-a-vis the United States has not been positive in the entire period under consideration, which

⁹The ordering of the variables in Figure 2 implies that innovations in interest rates simultaneously affect exchange rates but innovations in exchange rates do not simultaneously affect interest rates. However, reversing the ordering so that innovations in exchange rates simultaneously affect interest rates but not vice-versa does not change the result, cf. the appendix. Furthermore, preliminary implementation of impulse response functions in a system containing the 3-month money market interest rate show that the impulse response functions are qualitatively similar when this interest rate is included in the system instead of the long term interest rate. However, data on this short term rate is not available ultimo month in the entire sample period.

suggests that other factors, possibly the use of derivatives, existence of foreign production and limited exchange rate pass through, also might play a role. Unfortunately, data on these variables are not available.

The percentage of the 12-Month Forecast Error Variance explained by innovations in each variable are shown in Table 8.

Table 8: Percentage of 12-Month Forecast Error Variance Explained by Innovations in Each Variable

Variable explained	By innovations in			
	Industrial production	Interest rate	Exchange rate	Stock return
Industrial production	90.8	4.8	1.0	3.4
Interest rate	1.8	90.4	1.9	5.9
Exchange rate	4.7	7.3	86.3	1.7
Stock return	0.9	4.9	2.3	91.9

Note: The forecast error variance is derived from the VAR model specified in the first difference of each of the four variables. The VAR model contains three lags of each variable in first differences and a constant. The table shows the percentage of the 12-month forecast error variance in the first difference of variable *i* explained by innovations in variable *j*.

$$FEVD_{ij} = \frac{\sum_{s=0}^{11} c_{ij}(s)^2}{\sum_{j=1}^4 \sum_{s=0}^{11} c_{ij}(s)^2} \times 100$$

The ordering of the variables are the same as in Figure 2 and all forecast error variances has converged on a 12 months horizon.

As it appears from Table 8, 4.9 percent of the 12-Month Forecast Error Variance in the return on the stock market is explained by innovations in the interest rate, 2.3 percent by innovations in the exchange rate and 0.9 percent by innovations in industrial production. In this sense, innovations in the interest rate are the most important of the three variables in explaining the return on the stock market and innovations in exchange rates is the second most important variable. This is in accordance with the impression from Figure 2.

5 Concluding Remarks

In this paper, the dynamic interaction between stock market values, exchange rates and interest rates has been investigated by means of innovation accounting in a VAR model, providing a first step in the direction of a more comprehensive picture of the relation between exchange rates and stock market values. In particular, the approach allows for a distinction between a change in stock returns induced by a change in exchange rates and by a change in interest rates. In the first case, an observed relation between stock returns and exchange rate movements may both reflect a direct exchange rate effect and an exchange rate associated interest rate effect, and in the second case, the direct interest rate effect may be accompanied by an interest rate associated exchange rate effect.

Applying the framework to monthly data on stock market values, exchange rates and interest rates in Denmark, the main findings of the paper are, that an increase in the interest rate induce an appreciation of the exchange rate and that the correlation between interest rates and exchange rates results in a prolonged fall in the return on the stock market, approximated by the percentage, monthly change in the stock market index. Furthermore, a depreciation of the exchange rate does not induce a consistent change in the interest rate, but results in an increase in the return on the stock market, also for an extended period of time. Hence, by differentiating between exchange rate exposure induced by a change in the interest rate and by a change in the exchange rate, respectively, the paper adds insight into the channels through which firms on the Danish stock market are exposed to exchange rate movements. The results show that firms on the Danish stock market are exposed to exchange rate movements, both through a direct exchange rate effect and through an interest rate associated exchange rate effect and that there appears to be no exchange rate associated interest rate effect. The absence of an exchange rate associated interest rate effect shows that movements in the

exchange rate constitute an independent source of risk in relation to interest rates and the results should be viewed in light of the exchange rate regime in the period under consideration. With fixed exchange rates vis-a-vis Germany and floating exchange rates vis-a-vis the United States, a change in the interest rate is correlated with a change in the exchange rate vis-a-vis the United States, but a change in the exchange rate vis-a-vis the United States does not induce a change in interest rates, allowing exchange rate movements to constitute an independent source of risk in relation to interest rates.

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Appendix

The sensitivity of the results to different orderings

By placing a triangular structure on the G-matrix, the Choleski Decomposition implies that innovations in some variables do not contemporaneously affect some of the other variables. The identifying assumptions restrict the contemporaneous impact and not the lagged impact: The lagged terms are irrelevant for identification purposes, because both the primitive and the standard VAR include the same variables. Depending on the correlation between the residuals in the standard VAR, the ordering may have implications for the impulse response analysis. In order to investigate the sensitivity of the results to different orderings of the variables, the impulse response functions based on an ordering that allows the exchange rate to contemporaneously affect the interest rate, but not vice-versa, are traced out in Figure A1.

Figure A1: Impulse response functions

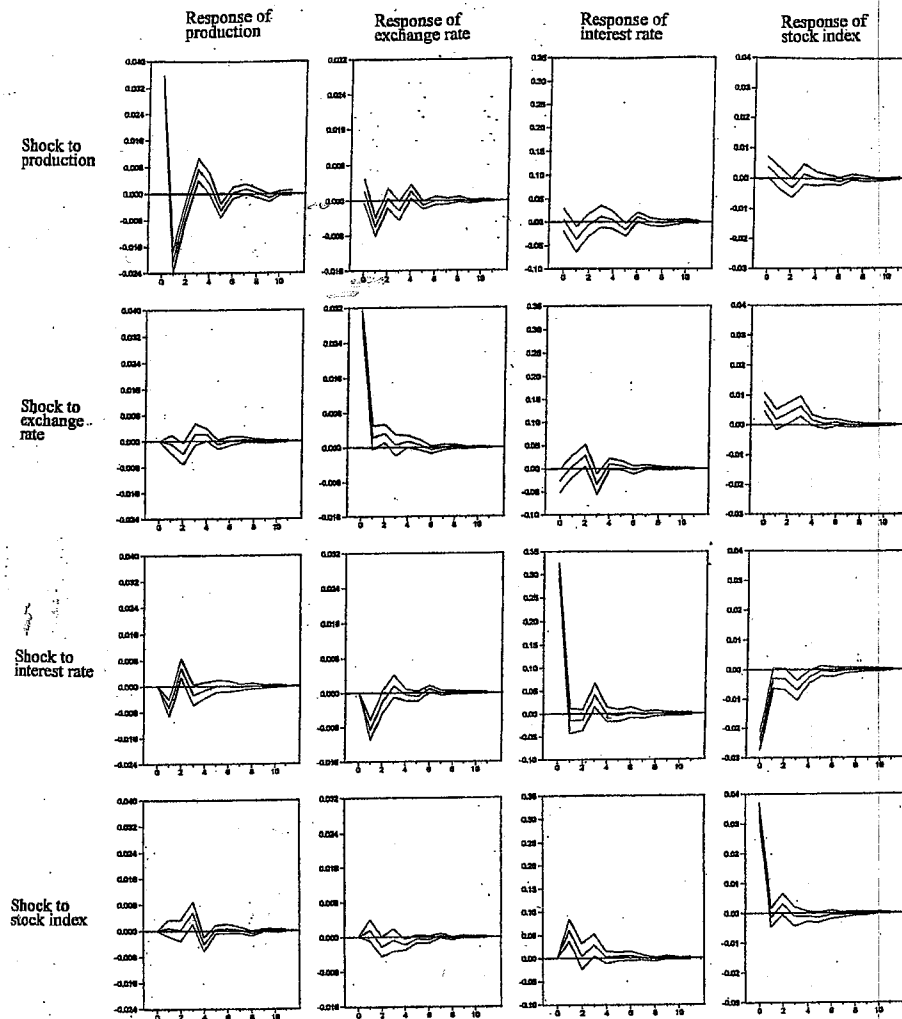


Figure A1 shows that the qualitative results are insensitive to this change in the ordering of the variables: An increase in the interest rate induces an appreciation of the exchange rate and a fall in the return on the stock market, and a depreciation of the exchange rate increases stock market returns, but does not induce a consistent change in the interest rate.

Furthermore, Table A1 shows the percentage of the 12-Month Forecast Error Variance explained by innovations in each variable based on the same ordering as in Figure A1.

Table A1: Percentage of 12-Month Forecast Error Variance Explained by Innovations in Each Variable

Variable explained	By innovations in			
	Industrial production	Exchange rate	Interest rate	Stock return
Industrial production	90.8	1.0	4.8	3.4
Exchange rate	4.7	86.3	7.3	1.7
Interest rate	1.8	1.9	90.4	5.9
Stock return	0.9	2.3	4.9	91.9

As it appears from Table A2, the percentage of the 12-Month Forecast Error Variance does not change as a result of the different ordering of the variables.

Chapter 4

On the Pricing of Exchange Rate Risk: An Industry Analysis

Bo Danø¹

Abstract

Are firms on the Danish stock market required to compensate investors for the risk associated with exchange rate changes? In the present paper, this question is discussed in the context of an arbitrage pricing framework. In the empirical analysis the market and innovations in the exchange rate orthogonal to the market are applied as two factors, and the model is estimated as an iterated nonlinear seemingly unrelated regression model. In contrast to related research for the stock market in the United States, the results indicate that exchange rate risk is priced on the Danish stock market. In particular, the unconditional risk premium attached to exchange rate exposure is positive and significant on a ten percent level, implying that positive exchange rate exposure is a source of higher risk and higher expected return. These results also indicate, that firms on the Danish stock market might be able to decrease the cost of capital by means of hedging.

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1 Introduction

This paper investigates whether there is an ex-ante premium to investors for the risk of exchange rate changes. In particular, if some sectors on the Danish stock market are sensitive to changes in exchange rates, are investors then compensated for the risk associated with exchange rate fluctuations? In a frictionless world with complete markets, the Modigliani-Miller Theorem suggests that investors do not necessarily need to be compensated for the risk of exchange rate changes, if this source of risk can be diversified away. In such a frictionless world shareholders can choose their own preferred risk profile given differences in exchange rate exposure of various sectors in the economy. On the other hand, the arbitrage pricing theory suggests that in an economy described by a number of pervasive factors, these factors might be priced in the sense that firms are required to pay investors for the risk of exchange rate changes, or - equally - investors will be willing to pay a price to avoid the risk associated with movements in exchange rates. Therefore, whether or not exchange rate risk is priced is an important question, since it might have implications for the cost of capital. If exchange rate risk is priced, investors might be willing to pay a price to avoid the risk associated with movements in exchange rates, and firms might be able to decrease the cost of capital by hedging against exchange rate fluctuations.

In the literature, several contributions have investigated whether or not exchange rate risk is priced on national stock markets, cf. among others Jorion (1991), Brown and Otsuki (1990) and Choi, Hiraki and Takezawa (1998). Jorion (1991) finds that while the relation between stock returns and the value of the dollar differs systematically across industries in the United States, the empirical

evidence does not suggest that exchange rate risk is priced on the stock market in the United States. Investigating the effect of macro-economic factors in the pricing of Japanese securities, Brown and Otsuki (1990) find that exchange rate risk is not priced in Japan, whereas Choi, Hiraki and Takezawa (1998) more recently have provided evidence that exchange rate risk is priced on the Japanese stock market. In order to investigate whether exchange rate exposure commands a risk premium on the Danish stock market, this paper investigates pricing of exchange rate risk within the context of the APT-model. In the empirical analysis, two factors are employed, i.e. the market and innovations in the exchange rate orthogonal to the market. Within this framework, the issue is whether the premium on exchange rate changes is significant, i.e., whether changes in exchange rates are priced in a manner consistent with the APT-model.

The paper is organized as follows. Section 2 reviews the APT- model and the assumptions to be tested, and section 3 describes the data employed in the paper. In order to avoid spurious pricing of the exchange factor because of possible correlation with a priced market, the exchange rate exposure for six different sectors in the economy purged for the influence of the market is estimated in section 4. Section 5 estimates the parameters in the model, and section 6 contains the concluding remarks.

2 The Model

To test whether exchange rate risk is priced in the sense of APT, two factors are applied, i.e. the market and the exchange rate and this can also be interpreted as a test of the CAPM against the alternative that the exchange rate factor is not diversifiable. With two factors, Ross's (1976) APT-model implies a linear relation between expected returns and the sensitivity

to market and exchange rate movements, i.e.:

$$(1) \quad E(R_t) = \delta_0 + \delta_1 \beta_i^m + \delta_s \beta_i^s$$

where R_t is the nominal return in excess of the risk-free rate for portfolio i , E is the expectations operator, and β_i^m and β_i^s denote sensitivity to market and exchange rate movements respectively, and where the exchange rate component is orthogonal to the market. Since $E(R_m) = \delta_0 + \delta_1 \beta_m^m + \delta_s \beta_m^s$, with $\beta_m^s = 0$ and since the market beta is equal to one, $\delta_1 = E(R_m) - \delta_0$. Inserting this in (1), the relation can also be expressed as:

$$(2) \quad E(R_t) = \delta_0 + [E(R_m) - \delta_0] \beta_i^m + \delta_s \beta_i^s$$

To test the pricing of exchange rate risk empirically, the rate of return on asset i at time t can be statistically decomposed into an expected component $E(R_{it})$ and an innovation, i.e.:

$$(3) \quad R_{it} = E(R_{it}) + \beta_i^m [R_{mt} - E(R_{mt})] + \beta_i^s F_{st} + \varepsilon_{it}$$

where $F_{st} = R_{st} - \gamma_0 - \gamma_1 R_{mt}$ is the residual of the ordinary least squares regression of the exchange rate movement R_{st} against the rate of return on the stock market. When there is some correlation between the exchange rate and the market, the exchange rate cannot be used directly as the second factor. Without orthogonalization, the second factor could appear to be priced because of a non-zero correlation with a priced market. Since equation (2) holds at every point in

time:

$$(4) \quad E(R_{it}) = \delta_0 + E(R_{mt}) \beta_i^m - \delta_0 \beta_i^m + \delta_s \beta_i^s$$

Inserting (4) in (3) yields:

$$(5) \quad R_{it} = \delta_0 (1 - \beta_i^m) + \delta_s \beta_i^s + \beta_i^m R_{mt} + \beta_i^s F_{st} + \varepsilon_{it}$$

In equation (5) the component of exchange rate risk orthogonal to the market is priced if the coefficient δ_s is significantly different from zero and equation (5) constitutes the model to be tested in this paper.

3 The data

With respect to stock market data, the stock market index as well as the stock index for six different sectors in the economy are applied. All these time series are in nominal terms and are measured ultimo month. Neither the stock market index nor the stock index for the six different sectors include dividends, so changes in these variables reflect capital gains or losses². The stock market index includes all firms listed on the Danish stock exchange. Furthermore, the stock index for the six different sectors is based on the classification constructed by Danmarks Statistik including banking, insurance, trading, shipping, industry and investment. Data on the stock index for these six sectors are shown in appendix 1.

Excess returns are constructed by subtracting the risk-free rate of return from the monthly rate of change in the stock market index and from the monthly

²Data on dividends do not exist on a monthly frequency.

rate of change in the stock index for the six different sectors, respectively. As a measure of the risk-free rate of return, a one month holding period return for a one Treasury-bill portfolio that is the shortest-term Treasury-bill with no less than 30 days to maturity, is calculated, cf. also McElroy and Burmeister (1988) and Ibbotson and Sinquefeld (2000). To measure holding period returns for the one-bill portfolio, the bill is priced as of the last trading day of the previous month-end and as of the last trading day of the current month. The price of the bill at time t , p_t , is given by $p_t = [1 - (rd/360)]$, where r is the decimal yield and rd is the number of days to maturity as of time t . The one month holding period return on the bill is the month-end price, p_2 , divided by the previous month-end price, p_1 , minus one, i.e. $(p_2/p_1) - 1$, times 100. This measure of the risk-free rate of return is well-suited for the present purpose, since it is assumed that the risk-free rate reflects realizable returns. Constructing the risk-free rate of return on the basis of the one-month holding period return on a one bill portfolio is in line with research conducted for other countries, cf. for example McElroy and Burmeister (1988), Jorion (1991). Data on the number of days to maturity, yield and holding period return for each month in the sample are shown in appendix 2.

With respect to innovations in the exchange rate, two different measures are applied. The first measure is the rate of change in the trade-weighted exchange rate defined such that an increase is a depreciation, and a decrease is an appreciation. However, since it might not be the trade-weighted exchange rate that matters for the individual firms, but rather bilateral exchange rates, depending on export and import markets, the trade-weighted exchange rate might be too crude a measure when the aim is to investigate the relation between stock market values and exchange rates on a sector level. The next question is then, what bilateral exchange rate should be applied in addition to the trade-weighted exchange rate? In this context, the bilateral exchange rate vis-a-vis the United States is applied, on

several grounds. First, the variability of this exchange rate has been high relative to the variability of the other important bilateral exchange rates entering into the trade-weighted exchange rate, due to Denmark's floating exchange rate regime vis-a-vis the United States. Second, movements in the exchange rate vis-a-vis the United States are significantly correlated with the percentage, monthly change in the stock market index in the period under consideration, cf. the results obtained in Chapter 2 and Chapter 3 of this thesis. Third, innovations in the exchange rate vis-a-vis the United States constitutes an independent source of risk in relation to the Danish stock market index, in the sense that the stock market index exhibits sensitivity to innovations in the exchange rate vis-a-vis the United States after accounting for the possible influence of interest rates, cf. Chapter 3. The exchange rate vis-a-vis the United States is also defined such that an increase is a depreciation, and a decrease is an appreciation.

The sample period starts in April 1990, corresponding to the first available data on the risk-free rate of return based on Treasury Bills, and ends in December 1999. This gives 116 observations on each variable. Table 1 shows the results from an augmented Dickey-Fuller (ADF) test applied to the percentage, monthly change in the two different exchange rates and the excess return on the stock market and the six different sectors, respectively. According to the augmented Dickey Fuller test, the null hypothesis of non-stationarity is rejected at a 5 percent level for all variables, cf. Table 1.

Table 1: Stationarity Test (ADF)

Variable	Constant and trend 5% critical value: -3.45 10% critical value: -3.15	Constant 5% critical value: -2.89 10% critical value: -2.58
Trade-weighted exchange rate	-3.71* (10)	-3.55* (10)
Exchange rate vis-a-vis the United States	-8.95* (0)	-8.98* (0)
Excess return (Stock market)	-9.65* (0)	-9.33* (0)
Excess return (Bank)	-9.64* (0)	-9.46* (0)
Excess return (Insurance)	-4.76* (2)	-9.91* (0)
Excess return (Trade)	-9.45* (0)	-9.21* (0)
Excess return (Shipping)	-10.27* (0)	-10.08* (0)
Excess return (Industry)	-8.73* (0)	-8.65* (0)
Excess return (Investment)	-9.01* (0)	-8.54* (0)

Note: The columns contain the test statistics from a regression with a constant plus a trend and with a constant only. The regressions include 10 lags to begin with, and the lag length is chosen by sequentially applying an F-test until the joint hypothesis $\beta_{s,1} = \beta_{s,L}$ is rejected for some L. Numbers in brackets denote number of lags in the final regression. The critical values are from Hamilton (1994). * denotes rejection of the null hypothesis of non-stationarity at a 5 percent level.

4 Exchange rate exposure orthogonal to the market

To avoid spurious pricing of the exchange rate factor because of possible correlation with a priced market, the model is examined for values of innovations in the exchange rate purged of the influence of the market, cf. also Jorion (1991). In order to obtain innovations in the exchange rate orthogonal to the market, the linear regression $R_{st} = \gamma_0 + \gamma_1 R_{mt} + F_{st}$ is estimated, where R_{st} is the percentage,

monthly change in the exchange rate, R_{mt} is the percentage, monthly excess return on the market, γ_0 is a constant, and F_{st} is the residual. The ordinary least squares estimates from this regression, implemented with the trade-weighted exchange rate and the bilateral exchange rate vis-a-vis the United States, respectively, are shown in Table 2.

Table 2: $R_{st} = \gamma_0 + \gamma_1 R_{mt} + F_{st}$

	γ_0	γ_1	R ²
Trade-weighted exchange rate	-0.01 (-0.14)	0.09 (5.16)	0.19
Exchange rate vis-a-vis the United States	0.13 (0.52)	0.22 (3.79)	0.11

Note: The t-statistics are shown in parenthesis.

Table 2 shows that γ_1 is significant in the period under consideration. In particular, an increase (decrease) in the excess return on the stock market is significantly correlated with a depreciation (appreciation) of the trade-weighted exchange rate and the exchange rate vis-a-vis the United States, respectively³. The approach is to give full weight to the data by assuming that the sample correlation between R_m and R_s is the true correlation and to orthogonalize R_s with respect to R_m by replacing R_s with the residuals from the regression in Table 2. By construction, these residuals are orthogonal to R_m . The exchange rate exposure orthogonal to the market for each of the six sectors is estimated as:

³Since the sample period under consideration is not the same as in the previous chapters of the thesis, and since this chapter is dealing with excess returns on the stock market, the results are not directly comparable with the findings in the previous chapters. However, that an increase (decrease) in stock market values is significantly correlated with a depreciation (appreciation) of the trade-weighted exchange rate and the exchange rate vis-a-vis the United States, respectively, is in line with the findings in the previous chapters.

$$(6) \quad R_{it} = \alpha_i + \beta_i^m R_{mt} + \beta_i^s F_{st} + \varepsilon_{it}$$

where R_{it} is the return on the i 'th sector ($i=1, \dots, 6$) in excess of the risk-free rate, R_{mt} is the return on the market in excess of the risk-free rate, and F_{st} is the residual from the regression in Table 2. Applying both the trade-weighted exchange rate and the exchange rate vis-a-vis the United States, the exchange rate exposure orthogonal to the market for the six different sectors are shown in Table 3.

Table 3: Exchange rate exposure of sector portfolios orthogonal to the market.

Sector	Trade-weighted exchange rate		Exchange rate vis-a-vis the United States	
	Market beta (β^m)	Exchange rate beta (β^s)	Market beta (β^m)	Exchange rate beta (β^s)
Bank	0.99** (13.6)	-0.28 (-0.7)	0.99** (13.7)	-0.08 (-0.7)
Insurance	0.84** (8.6)	0.54 (1.0)	0.84** (8.6)	0.06 (0.4)
Trade	0.95** (16.2)	-0.11 (-0.3)	0.95** (16.2)	-0.05 (-0.6)
Shipping	1.44** (14.1)	0.72 (1.3)	1.44** (14.3)	0.30* (1.9)
Industry	0.79** (21.6)	-0.15 (-0.7)	0.79** (21.6)	-0.03 (-0.5)
Investment	0.95** (12.1)	0.00 (0.0)	0.95** (12.2)	-0.13 (-1.1)

Note: The table shows the ordinary least square estimates from the regression $R_{it} = \alpha_i + \beta_i^m R_{mt} + \beta_i^s F_{st} + \varepsilon_{it}$. t-statistics are in parenthesis and * (**) denotes significance at the 5 (1) percent level.

Table 3 shows that the market beta is positive and highly significant in all cases, i.e. an increase (decrease) in the return on the market is significantly correlated with an increase (decrease) in the return on the sector portfolios. When innovations in the trade-weighted exchange rate orthogonal to the market are applied, the

results show that the sign of exchange rate exposure varies across sectors. However, the exchange rate beta is not significant at a conventional level for any of the sectors. Applying the exchange rate vis-a-vis the United States, however, the exchange rate beta is significant at the 5 percent level for Shipping, where a depreciation (appreciation) of the exchange rate vis-a-vis the United States is correlated with an increase (decrease) in excess returns. Since the exchange rate beta is only significant on a sector level when the exchange rate vis-a-vis the United States is applied, the following section focuses exclusively on the pricing of exchange rate risk in the context of the exchange rate vis-a-vis the United States.

5 Pricing of exchange rate risk in the sense of the APT

While the exchange rate exposure orthogonal to the market differs between the six sectors and is significant on a conventional level for shipping, the regressions in section 4 does not tell us whether the exchange rate factor is priced in the sense of the APT-model. This section investigates whether or not that is the case. To this end, the parameters estimated by ordinary least squares is applied, which yield the component of innovations in the exchange rate vis-a-vis the United States orthogonal to the market. Then the parameters δ_j and β_i in equation (5) are estimated jointly, with one equation applying to each of the six different sectors in the economy, i.e.

$$(7) \quad R_{1t} = \delta_0 - \delta_0 \beta^m_1 + \delta_s \beta^s_1 + \beta^m_1 R_{mt} + \beta^s_1 F_{st} + \varepsilon_{1t}$$

$$(8) \quad R_{2t} = \delta_0 - \delta_0 \beta^m_2 + \delta_s \beta^s_2 + \beta^m_2 R_{mt} + \beta^s_2 F_{st} + \varepsilon_{2t}$$

$$(9) \quad R_{3t} = \delta_0 - \delta_0 \beta^m_3 + \delta_s \beta^s_3 + \beta^m_3 R_{mt} + \beta^s_3 F_{st} + \varepsilon_{3t}$$

$$(10) \quad R_{4t} = \delta_0 - \delta_0 \beta^m_4 + \delta_s \beta^s_4 + \beta^m_4 R_{mt} + \beta^s_4 F_{st} + \varepsilon_{4t}$$

$$(11) \quad R_{5t} = \delta_0 - \delta_0 \beta^m_5 + \delta_s \beta^s_5 + \beta^m_5 R_{mt} + \beta^s_5 F_{st} + \varepsilon_{5t}$$

$$(12) \quad R_{6t} = \delta_0 - \delta_0 \beta^m_6 + \delta_s \beta^s_6 + \beta^m_6 R_{mt} + \beta^s_6 F_{st} + \varepsilon_{6t}$$

Equations (7) to (12) constitute a multivariate system of nonlinear, seemingly unrelated regressions, and the system is estimated by applying the iterated nonlinear seemingly unrelated regression method. This approach gives rise to joint estimates of asset sensitivities and risk prices that are strongly consistent and asymptotically normally distributed even in the absence of normally distributed errors. If the errors are assumed to be normally distributed, then iterating on the contemporaneous covariance matrix to obtain iterated nonlinear seemingly unrelated regressions (ITNLSUR) estimates provide tail equivalent maximum likelihood estimators, cf. McElroy, Burmeister and Wall (1985) and McElroy and Burmeister (1988). Applying the approach suggested by McElroy, Burmeister and Wall (1985) and by McElroy and Burmeister (1988) implies the parameters are estimated jointly. McElroy, Burmeister and Wall (1985) and McElroy and Burmeister (1988) argue, that by avoiding a two-step procedure which might introduce an errors-in-variables problem into the estimation, cf. also Shanken (1992), this positively affects the robustness of the resulting estimations, and they note that their method is similar in spirit to that of Gibbons (1982). The approach has also been applied in Choi, Hiraki and Takezawa (1998), Koutoulas and

Kryzanowski (1994), Brown and Otsuki (1990), among others⁴. The pricing coefficients are shown in Table 4.

Table 4: Pricing Coefficients

	δ_0	δ_s
April 1990 - Dec. 1999	1.55 (0.83)	6.02* (1.70)

Note: The table shows the pricing coefficients in the system $R_{it} = \delta_0 - \delta_0 \beta^m_i + \delta_s \beta^s_i + \beta^m_i R_{mt} + \beta^s_i F_{st} + \varepsilon_{it}$ ($i=1, \dots, 6$), containing the residual of the exchange rate vis-a-vis the United States orthogonal to the market, F_{st} . The factor risk exposure coefficients and risk premiums are estimated jointly in nonlinear iterations by applying the ITNLSUR model procedure in SAS. A fairly large number of different starting values for the iterative process have been tried. In all cases the iterative process gave rise to the estimates reported in this table or - for some starting values - the process did not converge. t-statistics are shown in parentheses. * denotes significance on a 10 percent level.

As it appears from Table 4, the exchange rate price coefficient (δ_s) is positive and significant at a 10 percent level. The positive and significant value of the exchange rate price coefficient indicates that firms with a positive exchange rate exposure - i.e. firms for which a depreciation of Dkr. vis-a-vis the United States is correlated with an increase in returns - are expected to have a higher rate of return relative to firms that are not exposed to fluctuations in the exchange rate vis-a-vis the United States. In other words, a positive exchange rate exposure is a source of higher risk and higher expected return. These results are in contrast with empirical findings for firms on the stock market in the United States, cf. Jorion (1991). Jorion (1991) finds that exchange rate risk is not priced in the United States, where investors do not seem to require compensation for the risk of exchange rate changes. Examining pricing of exchange rate risk in Japan, Hamao (1990) and Brown and Otsuki (1990) find that exchange rate risk is not priced in Japan, whereas Choi, Hiraki and

⁴Bekker, Dobbstein and Wansbeek (1996) note that the iterative seemingly unrelated regression method is demanding from a computational point of view since it involves a nonlinear problem in many parameters and show that the model also can be estimated as a reduced-rank regression.

Takezawa (1998) more recently have provided evidence that exchange rate risk is priced on the Japanese stock market. The values of the beta estimates obtained when equation (7) to (12) is estimated by applying the iterated nonlinear seemingly unrelated regression method are reported in Table 5.

Table 5: Beta estimates

	Market beta (β^m)	Exchange rate beta (β^s)
Bank	0.98** (13.7)	-0.03 (-0.6)
Insurance	0.86** (8.8)	-0.12 (-1.4)
Trade	0.94** (16.1)	0.03 (0.6)
Shipping	1.44** (14.4)	0.21 (1.5)
Industry	0.80** (22.9)	-0.04 (-0.8)
Investment	0.96** (12.3)	-0.18 (-1.8)

Note: The table shows the estimates of β^m and β^s in the system $R_{it} = \delta_0 + \delta_1 \beta^m + \delta_2 \beta^s + \beta^m R_{mt} + \beta^s F_{st} + \varepsilon_{it}$ ($i=1, \dots, 6$), containing the residual of the exchange rate vis-a-vis the United States orthogonal to the market, F_{st} . The system is estimated in nonlinear iterations by applying the ITSUR model procedure in SAS. A fairly large number of different starting values for the iterative process have been tried. In all cases the iterative process gave rise to the estimates reported in this table or - for some starting values - the process did not converge. t-statistic are shown in parentheses. ** denotes significance at the 1 percent level.

In Table 5, the market beta estimates are very similar to the estimates obtained when exchange rate exposure of the sector portfolios orthogonal to the market is examined by means of ordinary least squares, cf. Table 3. The exchange rate beta estimates do not correspond exactly to the estimates obtained in the ordinary least squares regressions. As compared with the results presented in Table 3, the sign of the exchange rate beta changes for Insurance and Trade and the numerical value of the t-statistic increases for Insurance, Industry and Investment and decreases for Bank and Shipping.

6 Concluding remarks

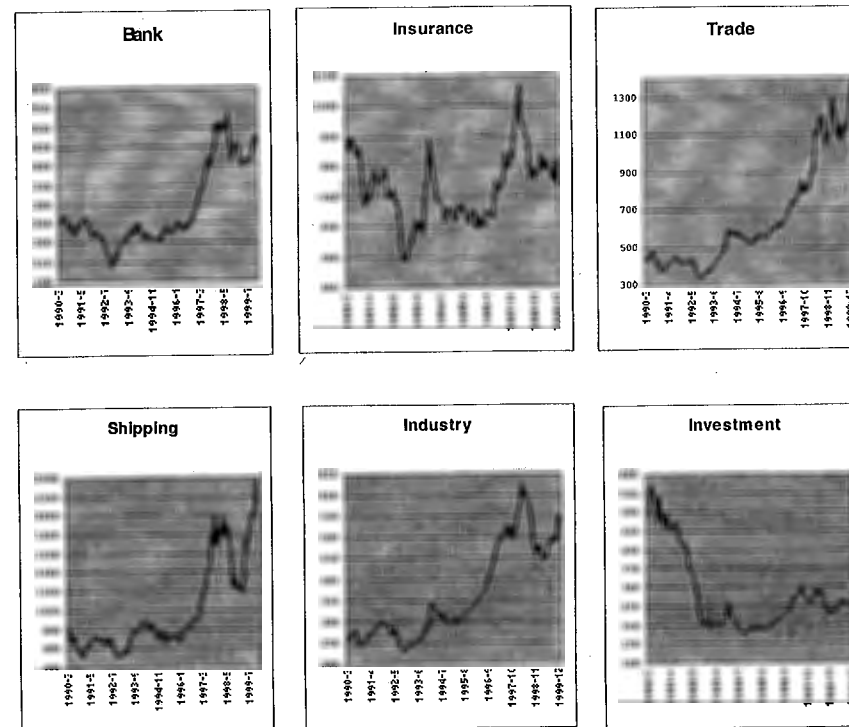
This paper has investigated whether firms on the Danish stock market are required to compensate investors for the risk associated with exchange rate movements. This issue is addressed in the context of an arbitrage pricing model and two factors are applied in the empirical analysis. Time-series on excess returns are constructed by subtracting the risk-free rate of return from the monthly rate of change in the stock market index and from the monthly rate of change in the stock index for six different sectors, respectively. To this end, the risk-free rate of return is calculated as the one month holding period return for a one Treasury-bill portfolio that is the shortest-term Treasury-bill with no less than 30 days to maturity. With respect to innovations in the exchange rate, two different measures are applied, namely the monthly rate of change in the trade-weighted exchange rate and in the bilateral exchange rate vis-a-vis the United States, respectively. Furthermore, to avoid spurious pricing of the exchange rate factor because of possible correlation with a priced market, the exchange rate exposure orthogonal to the market is estimated for six different sectors. When innovations in the trade-weighted exchange rate orthogonal to the market are applied, the sign of exchange rate exposure varies across sectors, but the exchange rate beta is not significant at a conventional level for any of the sectors. Applying the exchange rate vis-a-vis the United States, however, the exchange rate beta is significant for shipping, where a depreciation (appreciation) of the exchange rate vis-a-vis the United States is correlated with an increase (decrease) in excess returns.

Since the exchange rate beta is only significant on a sector level when the exchange rate vis-a-vis the United States is applied, the model is implemented with the market as the first factor and the exchange rate vis-a-vis the United States - purged of the influence of the market - as the second factor. Estimating the system as an iterated nonlinear seemingly unrelated regression model, the unconditional

risk premium attached to exchange rate exposure is found to be positive and significant on a ten percent level. The positive and significant exchange rate price coefficient indicates that firms with a positive exchange rate exposure - i.e. firms for which a depreciation of Dkr. vis-a-vis the United States is correlated with an increase in returns - are expected to have a higher rate of return relative to firms that are not exposed to fluctuations in the exchange rate vis-a-vis the United States. In other words, a positive exchange rate exposure is a source of higher risk and higher expected return.

These results are in contrast to empirical findings for the stock market in the United States. In particular, Jorion (1991) finds that exchange rate risk is not priced in the United States, where investors do not seem to require compensation for the risk of exchange rate changes. For other stock markets, such as Japan, the results are more mixed. Hamao (1990) and Brown and Otsuki (1990) find that exchange rate risk is not priced in Japan, whereas Choi, Hiraki and Takezawa (1998) more recently have provided evidence that exchange rate risk is priced on the Japanese stock market. Since the pricing of exchange rate risk on the Danish stock market implies that firms are required to pay investors for the risk of exchange rate changes, then - by the same token - investors will be willing to pay a price to avoid the risk associated with movements in exchange rates. Therefore, the results indicate that firms on the Danish stock market might be able to decrease the cost of capital by hedging against exchange rate movements.

Appendix 1: The stock index for the different sectors



Note: The data have been provided by the Copenhagen Stock Exchange

Appendix 2: Construction of one month holding period return

Month	ID Code	Days to maturity (Previous month-end)	Yield (Previous month-end)	Days to maturity (Current month-end)	Yield (current month-end)	Holding period return (percent)
April	307	93	0.114	65	0.1093	1.0
May	307	65	0.1093	32	0.1057	1.1
June	315	123	0.1045	93	0.1035	0.9
July	315	93	0.1035	62	0.0992	1.0
Aug	315	62	0.1052	31	0.1037	0.8
Sep	323	124	0.1045	95	0.1048	0.9
Oct	323	95	0.1048	63	0.1014	1.0
Nov	323	63	0.1014	33	0.1015	0.9
Dec	331	123	0.1044	94	0.1036	0.9
Jan (91)	331	94	0.1036	61	0.102	1.0
Feb	331	61	0.102	33	0.103	0.8
Marts	358	123	0.101	95	0.0971	1.0
April	358	95	0.0971	62	0.0985	0.9
May	358	62	0.0985	31	0.0934	1.0
June	366	123	0.0992	94 ⁸	0.0928	0.8
July	366	94	0.0928	62	0.0944	0.8
Aug	366	62	0.0944	31	0.096	0.8
Sep	374	123	0.0977	95	0.0979	0.8
Oct	374	95	0.0979	63	0.0948	0.9
Nov	374	63	0.0948	32	0.0935	0.8
Dec	382	122	0.096	91	0.1005	0.7
Jan (92)	382	91	0.1005	61	0.0995	0.9
Feb	382	61	0.0995	32	0.099	0.8
Marts	390	123	0.0983	92	0.1	0.8
April	390	92	0.1	62	0.1006	0.8
May	390	62	0.1006	31	0.099	0.9
June	404	124	0.0997	93	0.1035	0.8
July	404	93	0.1035	62	0.107	0.9
Aug	404	62	0.107	33	0.1105	0.9
Sep	412	128	0.1116	96	0.125	0.7
Oct	412	96	0.125	65	0.1057	1.4
Nov	412	65	0.1057	37	0.125	0.6
Dec	420	125	0.1109	92	0.1375	0.4
Jan (93)	420	92	0.1375	61	0.1181	1.5
Feb	420	61	0.1181	33	0.145	0.7

Marts	439	124	0.135	92	0.1118	1.8
April	439	92	0.1118	62	0.0973	1.2
May	439	62	0.0973	33	0.0873	0.9
June	447	125	0.1234	93	0.0744	2.4
July	447	93	0.0744	63	0.1236	-0.2
Aug	447	63	0.1236	31	0.105	1.0
Sept	455	125	0.097	95	0.085	1.1
Oct	455	95	0.085	65	0.0734	0.9
Nov	455	65	0.0734	33	0.0641	0.8
Dec	463	125	0.0701	97	0.0623	0.8
Jan (94)	463	97	0.0623	67	0.0569	0.6
Feb	463	67	0.0569	38	0.0603	0.4
Marts	471	125	0.058	93	0.0595	0.5
April	471	93	0.0595	62	0.0581	0.5
May	471	62	0.0581	31	0.0678	0.4
June	4981	125	0.058	95	0.061	0.4
July	4981	95	0.061	65	0.0575	0.6
Aug	4981	65	0.0575	33	0.0583	0.5
Sept	5012	124	0.065	94	0.0615	0.7
Oct	5012	94	0.0615	65	0.0577	0.6
Nov	5012	65	0.0577	33	0.0596	0.5
Dec	5368	124	0.0595	93	0.0595	0.5
Jan(95)	5368	93	0.0595	62	0.0556	0.6
Feb	5368	62	0.0556	34	0.0569	0.4
Marts	5442	125	0.0593	94	0.0726	0.2
April	5442	94	0.0726	65	0.0656	0.7
May	5442	65	0.0656	33	0.0658	0.6
June	5525	124	0.0638	94	0.0648	0.5
July	5525	94	0.0648	65	0.061	0.6
Aug	5525	65	0.061	32	0.0563	0.6
Sept	5608	124	0.0559	94	0.0553	0.5
Oct	5608	94	0.0553	63	0.0542	0.5
Nov	5608	63	0.0542	33	0.05	0.5
Dec	5798	122	0.0492	92	0.0445	0.5
Jan(96)	5798	92	0.0445	60	0.0423	0.4
Feb	5798	60	0.0423	32	0.0429	0.3
Marts	5871	123	0.0428	93	0.0397	0.4
April	5871	93	0.0397	62	0.036	0.4
May	5871	62	0.036	31	0.0383	0.3

June	5954	123	0.038	94	0.0369	0.3
July	5954	94	0.0369	62	0.0368	0.3
Aug	5954	62	0.0368	31	0.035	0.3
Sept	6093	124	0.036	96	0.0348	0.3
Oct	6093	96	0.0348	63	0.0346	0.3
Nov	6093	63	0.0346	33	0.0342	0.3
Dec	6176	122	0.0355	94	0.0351	0.3
Jan(97)	6176	94	0.0351	61	0.0351	0.3
Feb	6176	61	0.0351	31	0.035	0.3
Marts	6259	122	0.0354	96	0.0363	0.2
April	6259	96	0.0363	61	0.035	0.4
May	6259	61	0.035	31	0.0352	0.3
June	6333	123	0.0358	92	0.0348	0.3
July	6333	92	0.0348	61	0.0351	0.3
Aug	6333	61	0.0351	32	0.0348	0.3
Sept	6416	156	0.03701	124	0.0368	0.4
Oct	6416	124	0.0368	93	0.0389	0.3
Nov	6416	93	0.0389	65	0.0384	0.3
Dec	6416	65	0.0384	33	0.0376	0.4
Jan(98)	6689	121	0.0396	90	0.0373	0.4
Feb	6689	90	0.0373	62	0.0395	0.3
Marts	6689	62	0.0395	30	0.0374	0.4
April	6762	124	0.0381	94	0.0386	0.3
May	6762	94	0.0386	64	0.0416	0.3
June	6762	64	0.0416	33	0.0389	0.4
July	6846	124	0.0392	93	0.0391	0.3
Aug	6846	93	0.0391	62	0.0422	0.3
Sept	6846	62	0.0422	32	0.0472	0.3
Oct	6929	123	0.047	93	0.0433	0.5
Nov	6929	93	0.0433	62	0.0413	0.4
Dec	6929	62	0.0413	32	0.04	0.4
Jan(99)	7067	123	0.0372	93	0.0347	0.4
Feb	7067	93	0.0347	63	0.0348	0.3
Marts	7067	63	0.0348	32	0.033	0.3
April	7141	123	0.0322	93	0.0296	0.3
May	7141	93	0.0296	62	0.0305	0.2
June	7141	62	0.0305	32	0.0291	0.3
July	7224	123	0.0298	93	0.0305	0.2
Aug	7224	93	0.0305	61	0.0297	0.3

Sept	7224	61	0.0297	31	0.0292	0.3
Oct	7307	123	0.0324	94	0.0339	0.2
Nov	7307	94	0.0339	62	0.0339	0.3
Dec	7307	62	0.0339	33	0.0324	0.3

Note: The holding period return is calculated as $[(P_t/P_0)-1]*100$. $P_t = [1-(rd/360)]^t$, where r is the decimal yield and d is the number of days to maturity as of time t .

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Chapter 5

On the Pricing of Exchange Rate Risk: A Firm Level Analysis

Bo Danø¹

Abstract

This paper investigates exchange rate exposure for firms within the shipping sector and examine pricing of exchange rate risk in the context of an arbitrage pricing framework. The main findings are, that for four of the largest firms in this sector, a depreciation (appreciation) of the exchange rate vis-a-vis the United States is significantly correlated with an increase (decrease) in excess returns. Furthermore, the exchange rate price coefficient is not significant when the framework contains nine firms within the sector, but the exchange rate price coefficient is significant at the ten percent level when the system contains five sectors and one of the firms which are found to be significantly exposed to exchange rate movements.

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1 Introduction

Motivated by some evidence of significant exchange rate exposure for the shipping sector in Denmark, this paper conducts a more comprehensive investigation of exchange rate exposure for firms within this sector and examine the pricing of exchange rate risk. In the literature, several contributions have investigated whether or not exchange rate risk is priced on national stock markets, cf. among others Jorion (1991), Brown and Otsuki (1990) and Choi, Hiraki and Takezawa (1998). Jorion (1991) finds that while the relation between stock returns and the value of the dollar differs systematically across industries in the United States, the empirical evidence does not suggest that exchange rate risk is priced on the stock market in the United States. Investigating the effect of macro-economic factors in the pricing of Japanese securities, Brown and Otsuki (1990) find that exchange rate risk is not priced in Japan, whereas Choi, Hiraki and Takezawa (1998) more recently have provided evidence that exchange rate risk is priced on the Japanese stock market

In this paper, pricing of exchange rate risk is discussed in the context of the arbitrage pricing framework. In the empirical analysis, the market and innovations in the exchange rate orthogonal to the market are applied as the two factors in order to empirically investigate whether exchange rate exposure commands a risk premium for firms in the shipping sector. Within this framework, the issue is whether the premium on exchange rate changes is significant, i.e. whether changes in exchange rates are priced in a manner consistent with the APT-model.

The paper is organized as follows: Section 2 reviews the APT- model and the assumptions to be tested, and section 3 describes the data employed in the

paper. In order to avoid spurious pricing of the exchange factor because of possible correlation with a priced market, the exchange rate exposure for nine firms in the shipping sector purged for the influence of the market is estimated in section 4. Section 5 estimates the parameters in the model, and section 6 contains the concluding remarks.

2 The Model

To test whether exchange rate exposure is priced in the sense of APT, two factors are applied, i.e. the market and the exchange rate, and this can also be interpreted as a test of the CAPM against the alternative that the exchange rate factor is not diversifiable. With two factors, Ross's (1976) APT-model implies a linear relation between expected returns and the sensitivity to market and exchange rate movements, i.e.:

$$(1) \quad E(R_i) = \delta_0 + \delta_1 \beta_i^m + \delta_s \beta_i^s$$

where R_i is the nominal return in excess of the risk-free rate for portfolio i , E is the expectations operator, and β_i^m and β_i^s denote sensitivity to market and exchange rate movements, respectively, and where the exchange rate component is orthogonal to the market. Since $E(R_m) = \delta_0 + \delta_1 \beta_m^m + \delta_s \beta_m^s$, with $\beta_m^s = 0$ and since the market beta is equal to one, $\delta_1 = E(R_m) - \delta_0$. Inserting this in (1), the relation can also be expressed as:

$$(2) \quad E(R_i) = \delta_0 + [E(R_m) - \delta_0] \beta_i^m + \delta_s \beta_i^s$$

In order to test the pricing of exchange rate exposure empirically, the rate of return on asset i at time t can be statistically decomposed into an expected component $E(R_{it})$ and an innovation, i.e.:

$$(3) \quad R_{it} = E(R_{it}) + \beta_i^m [R_{mt} - E(R_{mt})] + \beta_i^s F_{st} + \varepsilon_{it}$$

where $F_{st} = R_{st} - \gamma_0 - \gamma_1 R_{mt}$ is the residual of the ordinary least squares regression of the exchange rate movement R_{st} against the rate of return on the stock market. When there is some correlation between the exchange rate and the market, the exchange rate cannot be used directly as the second factor. Without orthogonalization, the second factor could appear to be priced because of a non-zero correlation with a priced market. Since equation (2) holds at every point in time:

$$(4) \quad E(R_{it}) = \delta_0 + E(R_{mt}) \beta_i^m - \delta_0 \beta_i^m + \delta_s \beta_i^s$$

Inserting (4) in (3) yields:

$$(5) \quad R_{it} = \delta_0 (1 - \beta_i^m) + \delta_s \beta_i^s + \beta_i^m R_{mt} + \beta_i^s F_{st} + \varepsilon_{it}$$

In equation (5), the component of exchange rate risk orthogonal to the market is priced if the coefficient δ_s is significantly different from zero, and equation (5) represents the model to be tested in this paper.

3 The data

As for the data on stock market values, the stock market index, the stock index for five sectors in the economy and the stock index for the nine largest firms - measured in terms of capital - in the shipping sector, are applied. All these time series are in nominal terms and are measured ultimo month. Neither the stock market index, the stock index for the five different sectors or the stock index for the nine largest firms in the shipping sector include dividends, so changes in these variables reflect capital gains or losses². The stock market index include all firms listed on the Danish stock exchange, and the stock index for the five different sectors is based on the classification constructed by Danmarks Statistik, and include bank, insurance, trade, industry and investment. The nine largest firms in the shipping sector, measured in terms of capital, is D/S 1912 A, D/S 1912 B, D/S Svendborg A, D/S Svendborg B, DFDS, Lauritzen, D/S Norden, D/S Torm and Progress B. Stock prices for these nine firms are shown in the appendix.

Excess returns are constructed by subtracting the risk-free rate of return from the monthly rate of change in the stock market index, the monthly rate of change in the stock index for the five different sectors and from the monthly rate of change in the stock index for the nine largest firms in the shipping sector, respectively. As a measure of the risk-free rate of return, the one month holding period return for a one Treasury-bill portfolio that is the shortest-term Treasury-bill with no less than 30 days to maturity is calculated, cf. also McElroy and Burmeister (1988) and Ibbotson and Sinquefeld (2000). Each month a one bill portfolio containing the shortest-term bill having not less than one month to maturity is constructed. To measure holding period returns for the one-bill portfolio, the bill is priced as of the last trading day of the previous month-end and

²Data on dividends do not exist on a monthly frequency.

as of the last trading day of the current month. The price of the bill at time t , p_t , is given by $p_t = [1 - (rd/360)]$, where r is the decimal yield and d is the number of days to maturity as of time t . The one month holding period return on the bill is the month-end price, p_2 , divided by the previous month-end price, p_1 , minus one, i.e. $(p_2/p_1) - 1$, times 100. This measure of the risk-free rate of return is well-suited for the present purpose, since it is assumed that the risk-free rate reflects realizable returns. Constructing the risk-free rate of return on the basis of the one-month holding period return on a one bill portfolio is in line with research conducted for other countries, cf. for example McElroy and Burmeister (1988), Jorion (1991). Data on the number of days to maturity, yield and holding period return for each month in the sample have been shown in the appendix of Chapter 4.

With respect to innovations in the exchange rate, the exchange rate vis-a-vis the United States, defined such that an increase is a depreciation and a decrease is an appreciation, is applied. The sample period starts in April 1990, corresponding to the first available data on the risk-free rate of return based on Treasury Bills, and ends in December 1999. Altogether, this gives 116 observations on each variable. According to an augmented Dickey Fuller test, it cannot be rejected that all variables are stationary time series.

4 Exchange rate exposure orthogonal to the market

To avoid spurious pricing of the exchange rate factor because of possible correlation with a priced market, the model is examined for values of innovations in the exchange rate purged of the influence of the market, cf. also Jorion (1991). In order to obtain innovations in the exchange rate orthogonal to the market, the linear regression $R_{st} = \gamma_0 + \gamma_1 R_{mt} + F_{st}$ is estimated first, where R_{st} is the monthly

change in the exchange rate, R_m is the monthly excess return on the market, γ_0 is a constant and F_{st} is the residual. The ordinary least squares estimates from this regression, implemented with the exchange rate vis-a-vis the United States is shown in Table 1.

Table 1: $R_{st} = \gamma_0 + \gamma_1 R_{mt} + F_{st}$

	γ_0	γ_1	R ²
Exchange rate vis-a-vis the United States	0.13 (0.52)	0.22 (3.79)	0.11

Note: The t-statistics are shown in parenthesis.

Table 1 shows that γ_1 is significant in the period under consideration. In particular, an increase (decrease) in the excess return on the stock market is significantly correlated with a depreciation (appreciation) of the exchange rate vis-a-vis the United States³. The approach followed in this paper is to give full weight to the data by assuming that the sample correlation between R_m and R_s is the true correlation and to orthogonalize R_s with respect to R_m by replacing R_s with the residuals from the regression in Table 1. By construction, these residuals are orthogonal to R_m . The exchange rate exposure orthogonal to the market for each of the nine firms is estimated as:

³Since the sample period under consideration is not the same as in Chapter 2 and Chapter 3 of the thesis, and since this chapter is dealing with excess returns on the stock market, the results are not directly comparable with the findings in Chapter 2 and Chapter 3. However, that an increase (decrease) in stock market values is significantly correlated with a depreciation (appreciation) of the exchange rate vis-a-vis the United States is in line with the findings in Chapter 2 and Chapter 3.

$$(6) \quad R_{it} = \alpha_i + \beta_i^m R_{mt} + \beta_i^s F_{st} + \varepsilon_{it}$$

where R_{it} is the return on the i 'th firm ($i=1, \dots, 9$) in excess of the risk-free rate, R_{mt} is the return on the market in excess of the risk-free rate, and F_{st} is the residual from the regression in Table 1. Applying the exchange rate vis-a-vis the United States, the exchange rate exposure orthogonal to the market for the nine firms are shown in Table 2.

Table 2: Exchange rate exposure of firms in the Shipping sector, orthogonal to the market.

	Market beta (β^m)	Exchange rate beta (β^s)
D/S 1912 A	1.48** (12.43)	0.42* (2.23)
D/S 1912 B	1.49** (13.32)	0.39* (2.21)
D/S Svendborg A	1.45** (12.81)	0.32 (1.80)
D/S Svendborg B	1.51** (13.17)	0.36* (2.00)
DFDS	0.94** (5.32)	-0.24 (-0.86)
Lauritzen	0.85** (3.56)	0.25 (0.65)
D/S Norden	0.33 (1.80)	0.17 (0.57)
D/S Torm	1.00** (6.47)	0.17 (0.71)
Progress B	0.37 (0.65)	0.22 (0.24)

Note: The table shows the ordinary least squares estimates from the regression. $R_{it} = \alpha_i + \beta_i^m R_{mt} + \beta_i^s F_{st} + \varepsilon_{it}$. t-values are in parenthesis and *(**) denotes significance at the 5 (1) percent level.

Table 2 shows that the market beta is positive and highly significant for all firms with the exception of D/S Norden and Progress B and that the exchange rate beta is positive and significant at the five percent level for D/S 1912 A, D/S 1912 B and D/S Svendborg B and significant at the ten percent level for D/S Svendborg A. For these four firms, a depreciation (appreciation) of the exchange rate vis-a-vis the United States is correlated with an increase (decrease) in excess returns. In this context it should be noted that besides shipping, these firms are involved in oil production and both freight rates and oil prices are usually set in US dollar, cf. Tolofari (1989) and the Annual Report (1998) from Dampskibsselskabet af 1912. If the firms face prices that are exogenously determined in US dollar on the world market, then the firms cannot deliberately change their prices when the exchange rate fluctuates. If costs are relatively fixed in domestic currency, which may be a realistic assumption in the short run, then exchange rate changes may have strong effects on the firm's profitability and thereby on excess stock returns. However, it has not been possible to obtain any specific information on income and cost in US dollar for these firms.

5 Pricing of exchange rate risk in the sense of the APT

This section investigates whether the exchange rate factor is priced in the sense of the APT-model. In this context, the parameters γ estimated by ordinary least squares in section 4, is applied, which yields the component of innovations in the exchange rate vis-a-vis the United States orthogonal to the market. Then the parameters δ_j and β_j in equation (5) are estimated jointly, with one equation applying to each of the nine firms, i.e.

$$(7) \quad R_{1t} = \delta_0 - \delta_0\beta^m_1 + \delta_s\beta^s_1 + \beta^m_1R_{mt} + \beta^s_1F_{st} + \varepsilon_{1t}$$

$$(8) \quad R_{2t} = \delta_0 - \delta_0\beta^m_2 + \delta_s\beta^s_2 + \beta^m_2R_{mt} + \beta^s_2F_{st} + \varepsilon_{2t}$$

$$(9) \quad R_{3t} = \delta_0 - \delta_0\beta^m_3 + \delta_s\beta^s_3 + \beta^m_3R_{mt} + \beta^s_3F_{st} + \varepsilon_{3t}$$

$$(10) \quad R_{4t} = \delta_0 - \delta_0\beta^m_4 + \delta_s\beta^s_4 + \beta^m_4R_{mt} + \beta^s_4F_{st} + \varepsilon_{4t}$$

$$(11) \quad R_{5t} = \delta_0 - \delta_0\beta^m_5 + \delta_s\beta^s_5 + \beta^m_5R_{mt} + \beta^s_5F_{st} + \varepsilon_{5t}$$

$$(12) \quad R_{6t} = \delta_0 - \delta_0\beta^m_6 + \delta_s\beta^s_6 + \beta^m_6R_{mt} + \beta^s_6F_{st} + \varepsilon_{6t}$$

$$(13) \quad R_{7t} = \delta_0 - \delta_0\beta^m_7 + \delta_s\beta^s_7 + \beta^m_7R_{mt} + \beta^s_7F_{st} + \varepsilon_{7t}$$

$$(14) \quad R_{8t} = \delta_0 - \delta_0\beta^m_8 + \delta_s\beta^s_8 + \beta^m_8R_{mt} + \beta^s_8F_{st} + \varepsilon_{8t}$$

$$(15) \quad R_{9t} = \delta_0 - \delta_0\beta^m_9 + \delta_s\beta^s_9 + \beta^m_9R_{mt} + \beta^s_9F_{st} + \varepsilon_{9t}$$

Equations (7) to (15) constitute a multivariate system of nonlinear, seemingly unrelated regressions, and the system is estimated by applying the iterated nonlinear seemingly unrelated regression method. This approach gives rise to joint estimates of asset sensitivities and risk prices that are strongly consistent and asymptotically normally distributed even in the absence of normally distributed errors. If the errors are assumed to be normally distributed, then iterating on the contemporaneous covariance matrix to obtain iterated nonlinear seemingly unrelated regressions (ITNLSUR) estimates provide tail equivalent maximum likelihood estimators, cf. McElroy, Burmeister and Wall (1985) and McElroy and Burmeister (1988). Applying the approach suggested by McElroy, Burmeister and Wall (1985) and by McElroy and Burmeister (1988) implies the parameters are estimated jointly. McElroy, Burmeister and Wall (1985) and McElroy and Burmeister (1988) argue, that by avoiding a two-step procedure which might

introduce an errors-in-variables problem into the estimation, cf. also Shanken (1992), this positively affects the robustness of the resulting estimations, and they note that their method is similar in spirit to that of Gibbons (1982). The approach has also been applied in Choi, Hiraki and Takezawa (1998), Koutoulas and Kryzanowski (1994), Brown and Otsuki (1990), among others⁴. The pricing coefficients are shown in Table 3.

Table 3: Pricing Coefficients

	δ_0	δ_s
April 1990 - Dec. 1999	-1.22 (-1.46)	0.43 (0.36)

Note: The table shows the pricing coefficients in the system $R_{it} = \delta_0 - \delta_0 \beta_{it}^m + \delta_s \beta_{it}^s + \beta_{it}^m R_{mt} + \beta_{it}^s F_{st} + e_{it}$ ($i=1, \dots, 9$), containing the residual of the exchange rate vis-a-vis the United States orthogonal to the market, F_{st} . The factor risk exposure coefficients and risk premiums are estimated jointly in nonlinear iterations by applying the ITSUR model procedure in SAS. A fairly large number of different starting values for the iterative process have been tried. In all cases the iterative process gave rise to the estimates reported in this table or - for some starting values - the process did not converge. t-statistics are shown in parenthesis.

Table 3 shows that the exchange rate price coefficient (δ_s) is positive but not significant on a conventional level. The values of the beta estimates obtained when equation (7) to (15) is estimated by applying the iterated nonlinear seemingly unrelated regression method are reported in Table 4.

⁴Bekker, Dobbstein and Wansbeek (1996) note that the iterative seemingly unrelated regression method is demanding from a computational point of view since it involves a nonlinear problem in many parameters and show that the model also can be estimated as a reduced-rank regression.

Table 4: Beta estimates

	Market beta (β^m)	Exchange rate beta (β^s)
D/S 1912 A	1.47** (12.52)	0.41* (2.23)
D/S 1912 B	1.49** (13.42)	0.39* (2.22)
D/S Svendborg A	1.45** (13.02)	0.32 (1.80)
D/S Svendborg B	1.51** (13.30)	0.36* (1.99)
DFDS	0.95** (5.65)	-0.22 (-0.82)
Lauritsen	0.83** (3.62)	0.23 (0.61)
D/S Norden	0.34 (1.82)	0.18 (0.59)
D/S Torm	0.92** (6.14)	0.10 (0.42)
Progress B	0.45 (0.84)	0.30 (0.34)

Note: The Table shows the estimates of β^m and β^s in the system $R_{it} = \delta_0 - \delta_0 \beta_{it}^m + \delta_s \beta_{it}^s + \beta_{it}^m R_{mt} + \beta_{it}^s F_{st} + e_{it}$ ($i=1, \dots, 9$), containing the residual of the exchange rate vis-a-vis the United States orthogonal to the market, F_{st} . The system is estimated in nonlinear iterations by applying the ITSUR model procedure in SAS. A fairly large number of different starting values for the iterative process have been tried. In all cases, the iterative process gave rise to the estimates reported in this table or - for some starting values - the process did not converge. t-statistics are shown in parentheses. * (**) denotes significance at the 5 (1) percent level.

As it appears from Table 4, the market beta estimates are significant at the 1 percent level, with the exception of D/S Norden and Progress B, and the parameter values are fairly similar to the estimates obtained from the ordinary least squares regression, cf. Table 2. On an overall level, the exchange rate beta estimates are also fairly similar to results obtained in the ordinary least squares regression, and the exchange rate beta is significant at a five percent level for D/S 1912 A, D/S 1912 B and D/S Svendborg B and significant at the ten percent level for D/S Svendborg A.

These four firms are the largest firms within the shipping sector and that a depreciation (appreciation) of the exchange rate is correlated with an increase (decrease) in excess returns for these firms is in line with the results obtained for the shipping sector, cf. Chapter 4. This could indicate that it might be these firms that give rise to the results obtained for the shipping sector in Chapter 4. In this

context it should be noted that replacing the shipping sector in Chapter 4 with for example D/S 1912 A, i.e. investigating pricing of exchange rate risk in a system containing D/S 1912 A and the five main sectors (bank, insurance, trade, industry and investment), give rise to pricing coefficients that are fairly similar to the pricing coefficients obtained in Chapter 4, cf. Table 5.

Table 5: Pricing Coefficients

	δ_0	δ_s
April 1990 - Dec. 1999	0.93 (0.59)	5.21* (1.87)

Note: The Table shows the pricing coefficients in the system $R_{it} = \delta_0 - \delta_0\beta_{it}^m + \delta_s\beta_{it}^s + \beta_{it}^m R_{mt} + \beta_{it}^s F_{st} + \varepsilon_{it}$ ($i=1, \dots, 6$), containing the residual of the exchange rate vis-a-vis the United States orthogonal to the market, F_{st} . The factor risk exposure coefficients and risk premiums are estimated jointly in nonlinear iterations by applying the ITSUR model procedure in SAS. A fairly large number of different starting values for the iterative process have been tried. In all cases the iterative process gave rise to the estimates reported in this table or - for some starting values - the process did not converge. t-statistics are shown in parenthesis. * denotes significance at the 10 percent level.

Table 5 shows that the exchange rate price coefficient (δ_s) in this case also is positive and significant at the ten percent level. The positive and significant value of the exchange rate price coefficient shows that firms within the shipping sector with a positive exchange rate exposure - i.e. firms for which a depreciation of Dkr. vis-a-vis the United States is correlated with an increase in returns - are expected to have a higher rate of return⁵. In other words, a positive exchange rate exposure is a source of higher risk and higher expected return. Again, these results are in contrast with empirical findings for firms on the stock market in the United States, cf. Jorion (1991). In particular, Jorion (1991) finds that exchange rate risk is not priced in the United States, where investors do not seem to require compensation for the risk of exchange rate changes. Examining pricing of exchange rate risk in

⁵Similar results are obtained using eighter D/S 1912 B, D/S Svendborg A or D/S Svendborg B instead of D/S 1912 A.

Japan, Brown and Otsuki (1990) find that exchange rate risk is not priced in Japan, whereas Choi, Hiraki and Takezawa (1998) more recently have provided evidence that exchange rate risk is priced on the Japanese stock market. The values of the beta estimates obtained when the iterated nonlinear seemingly unrelated regression model was applied to the five sectors and D/S 1912 A are reported in Table 6.

Table 6: Beta estimates

	Market beta (β^m)	Exchange rate beta (β^s)
Bank	0.99** (13.70)	-0.03 (-0.55)
Insurance	0.85** (8.71)	-0.11 (-1.26)
Trade	0.94** (16.09)	0.04 (0.77)
D/S 1912A	1.49** (12.52)	0.26 (1.65)
Industry	0.80** (21.64)	-0.03 (-0.60)
Investment	0.95** (12.25)	-0.21* (-2.03)

Note: The Table shows the estimates of β^m and β^s in the system $R_{it} = \delta_0 - \delta_0\beta_{it}^m + \delta_s\beta_{it}^s + \beta_{it}^m R_{mt} + \beta_{it}^s F_{st} + \varepsilon_{it}$ ($i=1, \dots, 6$), containing the residual of the exchange rate vis-a-vis the United States orthogonal to the market, F_{st} . The system is estimated in nonlinear iterations by applying the ITSUR model procedure in SAS. A fairly large number of different starting values for the iterative process have been tried. In all cases, the iterative process gave rise to the estimates reported in this table or - for some starting values - the process did not converge. t-statistic are shown in parentheses. * (**) denotes significance at the 5 (1) percent level.

In Table 6, all market beta estimates are significant at the 1 percent level and the exchange rate beta estimates are significant at the 5 percent level for Investment and at a 10 percent level for D/S 1912A⁶.

⁶ Again, similar results are obtained using eighter D/S 1912 B, D/S Svendborg A or D/S Svendborg B instead of D/S 1912 A.

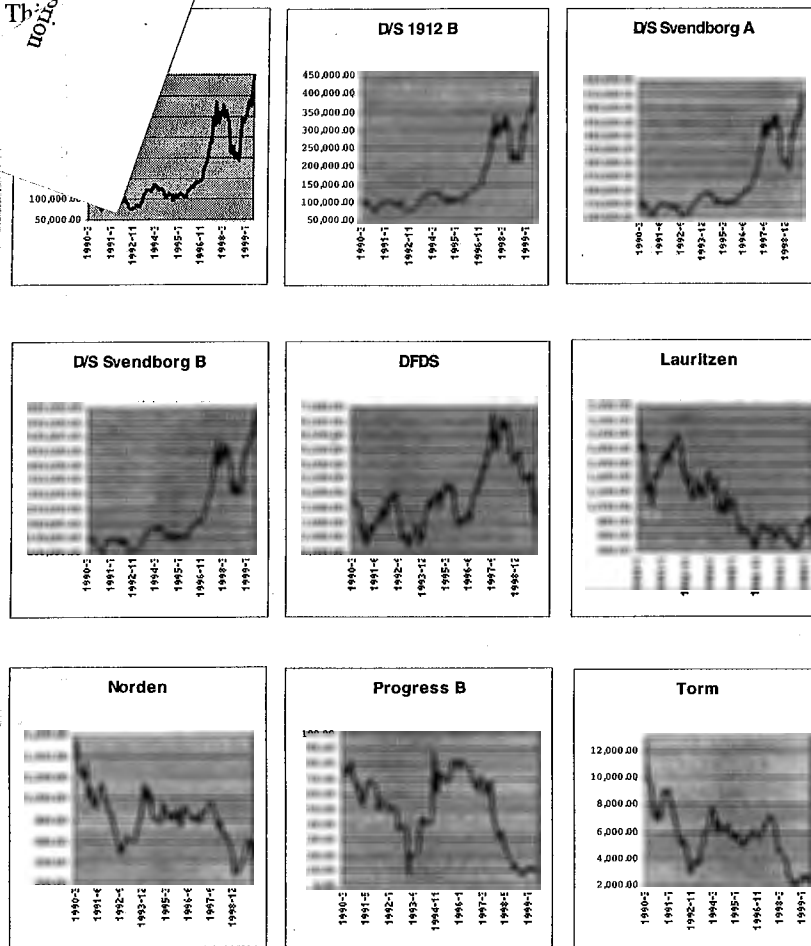
6 Concluding remarks

This paper has investigated exchange rate exposure and the pricing of exchange rate risk for the nine largest firms in the shipping sector. Applying monthly data on the stock market index, the stock index for these firms alongside with data on the risk free interest rate and the exchange rate vis-a-vis the United States, the findings are that exchange rate exposure orthogonal to the market is positive and significant for four of the firms under consideration. For these firms, a depreciation (appreciation) of the exchange rate vis-a-vis the United States is correlated with an increase (decrease) in excess returns. In this context it should be noted that these firms are involved in shipping and oil production and both freight rates and oil prices are usually set in US-dollar, cf. Tolofari (1989) and the Annual Report (1998) from Dampskibsselskabet af 1912. If the firms face prices that are exogenously determined in US dollar on the world market, then the firms cannot deliberately change their prices when the exchange rate fluctuates. Furthermore, if costs are relatively fixed in domestic currency, then exchange rate changes may have strong effects on the firm's profitability and thereby on excess returns. However, it has not been possible to obtain any specific information on income and costs in US dollar for these firms.

Furthermore, to investigate the pricing of exchange rate risk for the sample of firms, two factors are applied, i.e. the market and innovations in the exchange rate orthogonal to the market. Estimating the model as a system of seemingly unrelated regressions by applying the iterated nonlinear seemingly unrelated regression method, the findings are that the exchange rate price coefficient is not significant when the framework contains nine firms within this sector. However, the exchange rate price coefficient is significant at the ten percent level, when the system contains the five sectors and one of the firms which are found to be significantly exposed to exchange rate movements. Again, this results is in contrast

to empirical findings for the stock market in the United States. In particular, Jorion (1991) finds that exchange rate risk is not priced in the United States, where investors do not seem to require compensation for the risk of exchange rate changes. For other large stock markets, such as Japan, the results are more mixed. Hamao (1988) and Brown and Otsuki (1990) find that exchange rate risk is not priced in Japan, whereas Choi, Hiraki and Takezawa (1998) more recently have provided evidence that exchange rate risk is priced on the Japanese stock market.

Stock prices for the individual firms



Note: The data are from the Copenhagen Stock Exchange. For D/S 1912A, D/S 1912B, D/S Svendborg A and D/S Svendborg B, stock prices are for a face value of 1.000. In May 1998, these companies issued 4 new shares for each existing share. Hence, to ensure comparability, stock prices for these companies have been multiplied by 5 in the period from 1998:5 to 1999:12. Stock prices are for a face value of 1.000 for DFDS, of 20 for Lauritzen, of 100 for D/S Norden, of 50 for Progress B and of 1.000 for D/S Torm.

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Chapter 6

Summary in Danish

Afhandlingen består af en introduktion og fire selvstændige kapitler. Kapitlerne omhandler dels forskellige aspekter af valutakurseksponering og dels prisfastsættelse af valutakursrisiko, og alle de empiriske undersøgelser er gennemført på danske data.

Introduktionen, som er kapitel 1 i afhandlingen, indeholder en gennemgang og diskussion af en række væsentlige bidrag til den eksisterende litteratur på området, idet de efterfølgende kapitlers placering i forhold til denne litteratur samtidigt diskuteres.

I kapitel 2 inkorporeres regressionstilgangsvinklen til valutakurseksponering i en regime-skift-model, og den samtidige sammenhæng mellem aktiekurser og valutakurser undersøges inden for rammerne af denne model. Modellen identificerer to regimer. I det ene regime, der dominerer i en kortere periode, er der ikke nogen signifikant sammenhæng mellem aktiekurser og valutakurser. I det andet regime, der dominerer i en længere periode, er sammenhængen signifikant, idet en depreciering (appreciering) af den handelsvægtede valutakurs i dette regime er korreleret med en samtidig stigning (fald) i aktiekursen.

I kapitel 3 undersøges den dynamiske interaktion mellem aktiemarkedet, valutakurs og rente. Dette sker ved at benytte såkaldt innovation accounting i en vektor autoregressiv model. Ved at anvende denne tilgangsvinkel undersøges de dynamiske effekter på aktiemarkedet, induceret af henholdsvis ændringer i rente

og valutakurs. Resultaterne viser, at en stigning i renten inducerer en appreciering af valutakursen, og at korrelationen mellem rente og valutakurs resulterer i et længerevarende fald i afkastet på aktiemarkedet, approksimeret ved den procentvise, månedlige ændring i aktieindekset. En depreciering inducerer ikke en ensartet renteændring, men resulterer i en længerevarende stigning i afkastet på aktiemarkedet.

I kapitel 4 undersøges prisfastsættelse af valutakursrisiko på sektorniveau. I den empiriske analyse anvendes to faktorer, nemlig markedsindekset og innovationer i valutakursen, og systemet estimeres som en itereret ikke-lineær SUR model. I modsætning til relateret forskning for aktiemarkedet i USA viser de empiriske resultater, at valutakursrisiko prisfastsættes på det danske aktiemarked. Således er risikopræmien positiv og signifikant på et ti procent niveau. I kapitel 5 undersøges prisfastsættelse af valutakursrisiko på firmaniveau, idet der i dette kapitel fokuseres på firmaer inden for shipping sektoren. Ligesom i kapitel 4 anvendes markedsindekset og innovationer i valutakursen som to faktorer, og systemet estimeres igen som en itereret ikke-lineær SUR model. Resultaterne viser blandt andet, at for fire af de største virksomheder i denne sektor er en depreciering (appreciering) signifikant korreleret med en stigning (fald) i afkastet. Endvidere viser resultaterne, at risikopræmien er signifikant på et ti procent niveau, når prisfastsættelse undersøges i et system, der inkluderer de fem øvrige sektorer fra kapitel 4 samt et af disse fire firmaer.

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