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The impact of foreign exchange fluctuations on excess stock returns: Analysis of four European countries and industries

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Absract:

Diese Masterarbeit untersucht die Auswirkungen von Wechselkursschwankungen zwischen dem Euro und dem US-Dollar auf die Aktienrenditen von vier europäischen Branchen im Zeitraum von 2001 bis 2025. Der Schwerpunkt liegt auf vier Sektoren, nämlich dem Finanzsektor, dem Sektor für zyklische Konsumgüter, dem Telekommunikationssektor und dem Versorgungssektor. Die in die Analyse einbezogenen europäischen Länder sind Deutschland, Frankreich, Italien und Spanien. Ziel der Studie ist es, einen weiteren Beitrag zur Lösung des „Wechselkursrisikopuzzles" zu leisten, indem geprüft wird, ob neue methodische Fortschritte eine stärkere Signifikanz des Wechselkursrisikos erkennen lassen. Die Arbeit repliziert einen der neuesten Ansätze in diesem Forschungsbereich, nämlich ein Drei-Faktoren-Modell, das das globale Marktrisiko, das Zinsrisiko und das Währungsrisiko berücksichtigt und gemäß Tai (2024) mittels MGARCH geschätzt wird.

Die empirischen Ergebnisse deuten darauf hin, dass die europäischen Aktienmärkte symmetrisch auf Währungsschwankungen reagieren: Eine Abwertung des Euro gegenüber dem US-Dollar führt zu sinkenden Renditen an den europäischen Aktienmärkten, während eine Aufwertung die Renditen erhöht. Die Ergebnisse sind von besonderer Bedeutung, da trotz der Einbeziehung von Branchen mit nicht oder nur teilweise gehandelten Gütern festgestellt wurde, dass die Renditen ein signifikantes Restrisiko gegenüber dem Währungsrisiko aufweisen.

Absract:

This master's thesis examines the impact of exchange rate fluctuations between the euro and the US dollar on the stock returns of four European industries in the period from 2001 to 2025. The focus is on four sectors, namely the financial, cyclical consumer goods, telecommunications, and utilities sectors. The European countries included in the analysis are Germany, France, Italy, and Spain. The aim of the study is to provide a further contribution to solving the “exchange rate exposure puzzle” by testing whether new methodological advancements allow to find stronger significance in the exposure to currency risk. The thesis replicates on of the latest approaches in this field of research, namely a three-factor model that takes into account global market risk, interest rate risk, and currency risk, estimated via MGARCH, according to Tai (2024).

The empirical results suggest that European stock markets react symmetrically to currency fluctuations; a depreciation of the euro against the US dollar leads to falling returns in European stock markets, while an appreciation increases returns. The results are of particular significance since, despite the inclusion of industries with non-traded or only partially traded goods, it is found that returns show significant residual exposure to currency risk.

The impact of foreign exchange fluctuations on excess stock returns: Analysis of four European countries and industries

Table of Contents

List of figures and tables

Appendix figures and tables

1. Introduction

1.1 Research topic

Since the 1970s, and especially during the 1990s, due to accelerating globalization and the expansion of cross-border operations, multinational firms have faced increasing financial risks. Among these risks, the impact of currency movements on firms' value has received increasing attention, especially after the end of the fixed exchange rate system in 1973 (Tai, 2024). Business activities and investments carried out across several nations inherently involve foreign currencies, exposing firms to foreign exchange rate risk, as exchange rates do not remain constant. Exchange rate volatility is widely considered to significantly influence firm performance as it "affects operating cash flows and valuation through the translation, transaction, and economic effects of exchange rate exposure" (Choi and Prasad, 1995). Furthermore, the unexpected nature of these exchange rate movements can distort value in terms of product pricing decisions, budget planning, and net cash flow management, particularly within global supply chains (Pellegrino, et al., 2022). The sensitivity of a firm's real market value to fluctuations in foreign exchange rates over a specific period of time, as reflected in its stock market returns, is often referred to as exchange rate exposure (Adler and Dumas, 1984).

Although several theoretical equity pricing models ignore the relevance of exchange rate risk for firm value, in practice, most firms actively engage in managing this risk. This discrepancy can be attributed to the often-unrealistic assumptions underlying simplified theoretical models, which are useful for abstraction, but fail to capture the complexities of real-world corporate decision-making. Dufey and Srinivasulu (1983) effectively demonstrated that many arguments against foreign exchange hedging are flawed, and that corporate management of exchange rate risk can indeed have a significant impact on firm performance.

1.2 Research gap

Although over the years several empirical studies have examined the relationship between exchange rates and firm stock returns, attempting to statistically quantify its magnitude, the resulting estimates of exchange rate exposure are often weak or statistically insignificant (Bartram and Bodnar, 2007). This gap between the predictions of theoretical equity pricing models and the limited empirical evidence is commonly referred to as the “exposure puzzle.” In the past, a multitude of explanations have been explored, including methodological shortcomings and the endogenous nature of corporate hedging activities, the puzzle remains largely unresolved, especially for ex-post stock returns (Bartram and Bodnar, 2007). Only in recent years, thanks to new advancements in research methodologies, empirical studies were able to find stronger statistical significance in the relationship between contemporaneous exchange rate fluctuations and firm ex-post stock returns. In a recent study conducted by Tai (2024) this relationship is re-estimated by adopting a Multivariate Generalized Autoregressive Conditional Heteroskedasticity (MGARCH) model, finding that exchange rate exposure coefficients were significant in 86.11% of the sample industries. Moreover, it has been found that a 1% appreciation of the local currency with respect to the US dollar is associated with a 0.72% average increase in the weekly excess industry returns, which indicates that exchange rate exposure is both statistically and economically significant and that the exposure puzzle is primarily the consequence of methodological flaws in earlier research. Furthermore, the existing literature on exchange rate exposure has not given much attention to European financial markets compared to their U.S. counterparts (Parlapiano et al., 2017). The launch of the single European currency in 1999 offered a unique opportunity, acting as a "natural experiment," to empirically evaluate the economic consequences of decreasing exchange rate risk among member states. Subsequently, several investigations focused on evaluating the economic convergence within Europe following the establishment of the Euro and led to the following key observations:

- The currency unification led to a substantial decrease in the number of European non-financial firms displaying significant foreign exchange exposure, whereas similar companies outside of the European Monetary Union did not see a comparable risk reduction (Bartram and Karolyi, 2006; Koutmos and Knif, 2011)
- The introduction of a single currency significantly reduced stock return sensitivity to currency volatility, even when accounting for risk management strategies such as operational and financial hedging measures (Nguyen et al., 2007).
- The decrease in exchange rate risk following the Euro introduction also led to a decline in market risk exposure for non-financial firms. This is especially true for firms with international operations within Europe, as opposed to companies with no European foreign sales or assets (Hutson and O'Driscoll, 2010; Muller and Verschoor, 2006; Bartram and Karolyi, 2006).

Despite these important findings, the number of empirical studies investigating European financial markets is notably lower compared to the studies analyzing the impact of fluctuations in the U.S. Dollar on American companies (Parlapiano et al., 2017). This highlights the need to expand data collection and conduct deeper research in the Eurozone to better understand how geographical and structural differences influence firms' exposure to exchange rate risk.

1.3 Research question and relevance

Several explanations have been proposed to motivate the statistically weak relationship between exchange rate fluctuations and stock excess return variations, mainly focusing on two categories: methodological weaknesses in the empirical estimation or the effect of hedging strategies against currency risk employed by firms (Tai, 2024). The main methodological shortcomings and difficulties that have been identified in previous empirical papers are:

- The use of the traditional Ordinary Least Squares (OLS) approach, which assumes constant variance of firm returns. This can lead to inefficient parameter estimates and biased test statistics if the data presents conditional heteroskedasticity, which is a common characteristic inherent to both exchange rate and stock returns (Tai, 2024).
- The choice of exchange rate variables, such as multilateral trade-weighted rates as opposed to bilateral rates (Bartram and Bodnar, 2007), and the distinction between expected and unexpected exchange rate movements. Since expected movements should already be priced into current firm stock values, according to some studies, their inclusion may bias the measurement of exchange rate exposure (Parlapiano et al., 2017).
- The potentially lagged, non-linear, or asymmetric effects of exchange rate fluctuations on stock returns. Firstly, financial theory suggests that exposure may be partly nonlinear, as corporate cash flows are often a nonlinear function of exchange rates (Bartram and Bodnar, 2007). Secondly, as hypothesized by Bartov and Bodnar, stock return reactions may not be contemporaneous with exchange rate changes, due to systematic errors that investors make when estimating the impact of currency fluctuations on firm performance (Bartov and Bodnar, 1994). Thirdly, several studies acknowledge the potential asymmetry in the effects of currency appreciations versus depreciations on firm value (Bartov and Bodnar, 1994; He and Ng, 1998; Apergis et al., 2011; Parlapiano, et al., 2017; Tai, 2024). If these dynamics are not accounted for in the model framework, estimations may be inaccurate and results statistically weak.
- The potential collinearity of market risk and exchange risk factors. These two risk factors can be correlated or jointly influenced by macroeconomic shocks; thus, if not

modelled appropriately, for instance through orthogonalization, they can give rise to spurious relationships or underestimation of true exposure (Parlapiano et al., 2017).

A second explanation for the statistically weak link between currency movements and firm stock returns may lie in the fact that multinational firms often employ a range of hedging strategies to manage currency risk and effectively protect cash flows from exchange rate fluctuations (Choi and Prasad, 1995). Firms adopt various approaches to mitigate the impact of exchange rate volatility on their financial performance, cash flows, and stock returns. These strategies can be distinguished into two main categories: financial and operational hedging.

Financial hedging consists in taking offsetting financial positions to manage currency exposures, primarily using foreign currency derivatives or other financial instruments (Bartov and Bodnar, 1994). Conversely, operational hedging, also known as "natural" hedging, entails organizing a firm's operations in a way that minimizes currency risk, for example by matching revenues and costs in the same currency (Madura, 1989). The specific financial and operational tools available to firms for hedging their performance, returns, and cash flows against currency risk will be examined in greater detail in section 2.3, "Hedging instruments for exchange rate risk management".

As previously mentioned, recent methodological advancements provide promising developments to solve the exposure puzzle. Tai (2024) directly addresses the methodological shortcomings arising in previous research by employing a Multivariate Generalized Autoregressive Conditional Heteroskedasticity (MGARCH) methodology. This approach accounts for conditional heteroskedasticity inherent to stock returns and exchange rates and incorporates information from the entire variance-covariance matrix of errors, leading to more precise parameter estimates. Furthermore, in his modelling framework, Tai (2024) explicitly includes the asymmetric exchange rate exposure, accounting for the potential variations in firm behavior and stock returns during periods of currency appreciation versus depreciation. Tai's findings are based on a broad sample of industrialized, as well as emerging economies and indicate that exchange rate exposure is statistically significant and economically important for the vast majority (86.11%) of country-industry excess returns, with a substantial portion of them (32.26%) exhibiting asymmetric dynamics. Building upon this significant methodological contribution, this thesis aims to re-examine the exchange rate exposure puzzle within the European context. In particular, this study seeks to answer the following research question: *How do exchange rate fluctuations affect the ex-post country-industry returns of European industries?*

While this research does not try to provide a definitive solution to the "exposure puzzle", it aims to contribute to the literature by further investigating the relationship in the context of European industries. In particular, it focuses on looking for the potential factors explaining an industry's and a country's exposure level, such as the characteristics of a specific industry sector, the level of internationalization, as well as differences in the trade relations between European countries and the Unites States.

Foreign exchange risk has received increasing attention in the last years and is expected to become even more relevant given the increasingly uncertain geopolitical relations, which could potentially cause a shift in the U.S. dollar status, as well as increasing overall exchange rate volatility. Thus, understanding the factors determining exchange rate exposure and its implications for firm value is crucial for corporate decision-making, especially with respect to financial and operational hedging strategies. Additionally, as most of the literature has focused on U.S. multinationals, analyzing this relationship in the context of European firms could provide additional insights and help clarify the role of regional and structural differences in shaping foreign exchange exposure.

2. Literature review

2.1 Exchange rate and exchange rate risk

In today's global economy, we have a variety of national currencies serving as units of account, stores of value, and mediums of exchange. Since these currencies are not perfect substitutes and are typically confined to national borders, a foreign exchange (FX) market is necessary to facilitate international trade and investment. The exchange rate represents the price of one currency in terms of another, and it can be quoted either directly (foreign currency per unit of domestic currency) or indirectly (domestic currency per unit of foreign currency). Exchange rate systems can be fixed, where the rate remains stable due to institutional controls, or flexible, where it fluctuates based on market forces. Some countries adopt pegged exchange rate systems, which allow for periodic adjustments while maintaining some level of stability. Due to these differences and the variety of currencies globally, exchange rates are inherently volatile and uncertain. Fluctuations in exchange rates present a significant source of uncertainty for governments and multinational firms, since they impact their ability to sell abroad, increase the cost of foreign-sourced materials, decrease the firm's competitiveness domestically and internationally (Bradley and Moles, 2002), as well as impact the value of a multinationals' assets and debts (Papaioannou, 2006). More generally, fluctuations in exchange rates can potentially directly or indirectly cause a loss in the firm's cash flows, assets, liabilities, net profits, and stock value associated with an unhedged exchange rate movement (Madura, 1989). This risk, referred to as exchange rate risk, arises not only under floating exchange rate regimes but also under adjustable pegged systems. Even if we assume that purchasing power parity holds in the long run, short-term volatility remains unpredictable, making the perception of currency risk a key factor in corporate financial planning (Aliber, 1978). From an economic perspective, firms are exposed to foreign currency risk even when they do not directly involve in foreign operations or hold foreign currency assets, liabilities, or transactions (Adler and Dumas, 1984). If a company's customer base consists of importing or exporting firms which are highly sensitive to exchange rate fluctuations, the company's operations and stock prices themselves will also be exposed to exchange risk (Adler and Dumas, 1984).

Before diving deeper into notions regarding exchange rate risk and its management strategies, we will first provide a definition of what exchange rate risk is. Exchange rate risk, also called currency risk, is defined as the effect of unexpected exchange rate changes on the value of a firm. It is important to note that a currency is not risky because it is likely subject to devaluation, but instead because its appreciation or depreciation is determined by randomness, so what determines the risk of a currency is its unexpected fluctuations. Currency risk can be identified and quantified statistically by summarizing "the probability that the actual domestic purchasing power of home or foreign currency on a given future date will differ from its originally anticipated value" (Adler and Dumas, 1984). Following the categorization by Papaioannou (2006), we identify three types of exchange rate risk:

- *Transaction risk* refers to the exposure from foreign currency-denominated receivables, payables, or dividend payments, directly affecting cash flows. In international trade it is common for payments for goods or services to not be settled immediately upon delivery. Instead, there is often a time lag between the transfer of goods or services and the corresponding payment. Potential changes in the FX rate happening in the time window between transaction and payment is what gives rise to exchange rate transaction risk (Clark and Judge, 2009). For instance, if a European company agrees to receive payment in U.S. dollars, it is exposed to the risk that the euro may appreciate before the payment is received, thereby reducing the value of its earnings when converted into euros (Bodnar et al., 1998).

- *Translation risk,* also called balance sheet exchange risk, usually arises due to the consolidation of foreign subsidiaries into the parent company's financial statements, where exchange rate changes impact the valuation of assets and liabilities. Translation is usually measured in terms of net assets (assets less liabilities) in a foreign subsidiary exposed to potential exchange rate moves (Papaioannou, 2006). Depending on the accounting rules that apply to the parent firm, the translation of financial statements could be done at the end-of-period exchange rate or at the average exchange rate of the period. While income statements are typically translated at the average exchange rate for the period, balance sheet exposures of overseas subsidiaries are most commonly translated at the current exchange rate at the time of consolidation, making balance sheets more exposed to unexpected currency fluctuations. The bigger the portfolio of foreign-denominated assets, liabilities, and equities of a company, the higher the resulting translation risk (Papaioannou, 2006).
- *Economic risk,* also defined forecast risk or economic exposure, refers to the impact of exchange rate changes on companies' future revenues, competitiveness, and market worth. It reflects the "risk to the firm's present value of future operating cash flows from exchange rate movements" (Papaioannou, 2006). This risk extends beyond immediate accounting effects and incorporates the competitive situation of the firm (Bradley and Moles, 2002). Unexpected changes in exchange rates can represent an economic risk since they can cause fluctuations in domestic demand, employment, and produced output, impacting both internationally active, as well firms with pure domestic focus. Economic exposure affects firms on both the revenues side, including domestic sales and exports, and the operating expenses, such as input cost and imports (Papaioannou, 2006). This type of risk is often correlated with macroeconomic conditions, such as geopolitical instability and government regulations.

So far, we have focused our discussion on the concept of exchange rate risk. Another closely related but distinct concept is exchange rate exposure. While exchange rate risk refers to the likelihood that the domestic purchasing power of a foreign currency–denominated amount will deviate from its expected value, exposure is more specifically concerned with “what” and “how much” is at risk for a company. More precisely, Adler and Dumas (1984) define exposure as the amounts of foreign currencies representing the sensitivity of the future market value of any physical or financial asset to random variations in the future domestic purchasing powers of these foreign currencies, at some specific future date.

2.2 Relevance of exchange rate risk management

In today’s increasingly interconnected market, where supply chains and trade relations reach across several continents, only a small portion of firms remain unaffected by foreign exchange fluctuations. Companies engaging in international trade are inevitably exposed to changing currency prices across trading sessions, which can result in significant financial losses in case of unfavorable exchange rate movements. Strongly export-oriented firms may benefit from a weaker domestic currency, since the domestic products become more affordable for foreign trade partners. Conversely, the profits of more import-oriented firms may decrease when the domestic currency depreciates, since input and production costs become higher (Dominguez and Tesar, 2001). Furthermore, as underscored by Dominguez and Tesar, even firms who do not actively engage in international business, or that are active in non-traded sectors, may be indirectly impacted by foreign competition (Dominguez and Tesar, 2001). As a result, a solid understanding of foreign exchange risk management has become of fundamental importance in order to operate in the global economy (Batten et al., 1993). Additional evidence supporting the increasing importance of effective exchange rate risk management strategies emerges from the frequent currency crises occurred in recent decades (Papaioannou, 2006). Among these, the Asian financial crisis which hit Thailand, Indonesia, South Korea, Malaysia, and Philippines in the years 1997-1998 is an exemplary case of how fixed currency regimes and unhedged exchange rate risk can expose structural vulnerabilities in the financial sector and cause a deep systemic collapse. As explained by Radelet and Sachs (1998), two factors closely related to exchange rates contributed to magnifying the initial signs of distress. These factors include:

- Currency pegs and overvaluation: To maintain an exchange rate favorable to exports, most Asian economies adopted either explicit or implicit pegs to the U.S. dollar. Between 1995 and 1997, as the dollar appreciated against the yen, these currency pegs led to a significant appreciation in the real exchange rates of Asian countries. This, in turn, resulted in an overvaluation of their currencies, undermining export competitiveness and worsening current account balances (Radelet and Sachs, 1998).
- Unhedged foreign currency borrowing: Between 1990 and 1996, the fast growth of Asian economies attracted foreign private capital inflow. These foreign currency-denominated funds were typically channeled through domestic banks to local firms that had little or no exposure to international trade and generated revenues solely in local currency. This in turn created significant currency mismatches on bank balance sheets, most of which were unhedged. As a result, banks and firms became highly exposed to exchange rate risk and more vulnerable to currency depreciation (Radelet and Sachs, 1998).

In the mid 1990s the economic fundamentals of many Asian countries weakened. In particular, Thailand was dealing with an overvalued baht, increasingly high current account deficits, and growing short-term debt. Consequently, an increasing number of investors started selling their baht reserves in exchange for U.S. dollars, speculating that Thailand would not be able to maintain its currency peg. As a response, the Bank of Thailand intervened in the foreign exchange market by selling U.S. dollars from its reserves and buying baht, in an attempt to keep the currency stable. On July 2nd, 1997, growing market pressures forced Thailand to remove its peg and to devalue its currency relative to the U.S. dollar (Carson and Clark, 2013).

This development signed the beginning of a deep financial crisis across most of East Asian countries. As the exchange rate depreciated, firms with large amount of foreign currency-denominated debt faced a sharp increase in the domestic currency value of their external debts, leading many into distress and even insolvency (Carson and Clark, 2013). This, in turn, amplified the financial panic and transformed a liquidity problem into a broader solvency crisis and economic collapse (Radelet and Sachs, 1998). Not only Thailand, but most of East Asian countries faced a general pullback of funds from international investors, who believed the entire region to have similar financial vulnerabilities. The resulting rapid contagion from country to country called for international intervention to stabilize the Asian economies. The World Bank, the Asian Development Bank, the International Monetary Fund, and governments in the US, Europe, and the Asia-Pacific region provided financial assistance (Carson and Clark, 2013). The crisis was eventually contained and the combination of robust policies implemented by the impacted nations, together with the outside assistance from the international community allowed a subsequent robust recovery. Nonetheless, spillover effects were visible in some countries, in particular, several emerging economies in Latin America and Eastern Europe, such as Brazil and Russia, experienced severe balance-of-payments pressures in 1998. Although not attributable exclusively to a mismanagement of exchange rate risk, this crisis is a prime example of how unhedged currency risk can exacerbate initial signs of financial distress and generate spillover effects extending to the global level. Consequently, firms engaging in multinational operations nowadays implement a more prudent and structured management of currency risk, in order to reduce vulnerabilities from major currency fluctuations (Van Deventer et al., 2004).

2.3 Deviations from traditional theory: the rationale for exchange risk management

Despite practitioners highlight the importance of an effective exchange rate risk management, several financial and economic theories argue that corporate management of foreign exchange risk is unnecessary or even redundant. This chapter provides an overview of the principal theoretical frameworks suggesting that exchange rate risk management should not be priced into equity returns and examines how real-world conditions frequently deviate from these theoretical assumptions, ultimately exposing firms to currency risk.

2.3.1 Purchasing Power Parity theory

The first theory suggesting that exchange rate fluctuations should not impact firm performance is the Purchasing Power Parity (PPP) theorem. The history of purchasing power parity theory dates back to the 16th century, but it was introduced for the first time under the current name in the years after World War I by the Swedish economist Gustav Cassel. PPP theory essentially states that "the nominal exchange rate between two currencies should be equal to the ratio of aggregate price levels between the two countries, so that a unit of currency of one country will have the same purchasing power in a foreign country" (Taylor and Taylor, 2004). This theory is based on the core idea of the "law of one price" (LOP), which says that "identical goods should sell for the same price in two separate markets when there are no transportation costs and no differential taxes applied in the two markets (Krugman et al., 2012). Formally, the law of one price in its absolute version can be written as:

$$P_{i,t} = S_t P^*_{i,t} \quad i = 1,2,\cdots N$$

Where $P_{i,t}$ indicates the price of good i in terms of the domestic currency at time t, $P^*_{i,t}$ denotes the price of good i in terms of the foreign currency at time t, and S_t is the nominal exchange rate expressed as the domestic price of the foreign currency at time t(Sarno and Taylor, 2002).

The explanation for the LOP lies in the idea that in a perfect market, in case of price differences across countries, agents will take advantage of arbitrage opportunities, buying goods in low price markets and reselling them in the high price markets, until the prices naturally adjust to a level where no arbitrage is possible anymore (Sarno and Taylor, 2002). The relative version of LOP can be represented by the following equation:

$$\frac{P_{i,t+1}^{*}S_{t+1}}{P_{i,t+1}} = \frac{P_{i,t}^{*}S_{t}}{P_{i,t}} i = 1,2,\cdots N$$

Contrarily to the absolute LOP, stating that the foreign-currency denominated price of a good converted at the spot exchange rate should always equal the domestic price, the relative LOP does not imply prices equality at each point in time but simply states that percentage changes in domestic and foreign prices over time should match. The law of one price applied to the aggregate is essentially what we call the Purchasing Power Parity theory. Since prices of individual goods should be the same across markets if converted into the same currency, the same condition should hold for all identical goods sold in these markets (Krugman et al., 2012). Let us consider for example the cost of a basket of goods in the United States denominated in U.S. dollars and the cost of the same basket of goods in the European Union denominated in euros. PPP theory implies that the price of the U.S. basket of goods divided by the euro-dollar nominal exchange rate should be equal to the price of the basket of goods denominated in euros. This relationship can be written as:

$$\frac{CB_{€}}{E_{€/\$}} = CB_{\$}$$

By rewriting the right-hand side of the formula, we obtain the most common formulation of PPP theory, stating that PPP exchange rate (in this case euros per dollar) will be equal to the ratio of the costs of the two market baskets of goods denominated in local currency units (Krugman et al., 2012).

$$E_{€/\$}^{PPP} = \frac{CB_{€}}{CB_{\$}}$$

The main implication of PPP theorem for corporate management of exchange rate risk is that there should be no real exposure to this type of risk, because relative prices should remain constant despite currency movements. For example, if inflation is higher in Italy than in the U.S., the euro would depreciate against the U.S. dollar by a corresponding amount, theoretically neutralizing the effect on trade. This implies that, if for instance one unit of American wheat was exchanged for two units of Italian wine at the beginning of the year, the same exchange ratio will hold at the end of the year, since exchange rate should have compensated the change in nominal prices (Dufey and Srinivasulu, 1983). From this example we see that, if PPP held perfectly and without real-world imperfections, firms would not be exposed to exchange risk. Unfortunately, PPP theory does not account for several real-world imperfections that are relevant in corporate decision making. First, empirical tests have shown that exchange rate and price adjustments are not contemporaneous, but that there is a time lag in their relationship. Typically, PPP might hold when considering very long time horizons, but since companies usually have shorter planning horizons, they must account for potentially disruptive price changes following currency fluctuations (Dufey and Srinivasulu, 1983). Second, even if Purchasing Power Parity holds for aggregate price level indexes across countries, usually it does not hold for prices of individual goods. This suggests that the Law of One Price does not hold and that companies can be exposed to exchange rate risk when, for instance, the price level of the commodity traded is not offset by the increase in the general inflation level (Dufey and Srinivasulu, 1983). The third deviation from PPP, as explained by Dufey and Srinivasulu (1983), is the fact that, even if we assume that PPP and LOP hold, the prices of specific inputs and outputs of each company might change relative to each other due to exchange rate fluctuations, exposing the company to currency risk (Dufey and Srinivasulu, 1983).

To illustrate deviations from PPP on a more practical level, Taylor and Taylor (2006) introduce the example of the “Big Mac index” calculated by The Economist. This index was invented by The Economist in 1986 as a lighthearted guide to whether currencies are at their “correct” level according to PPP theory (The Economist, 2025). This index compares the price of a McDonald's Big Mac hamburger across different countries, converting them into a common currency, such as the U.S. dollar, using prevailing market exchange rates. The underlying principle is that if PPP held true, the Big Mac's price, when converted to dollars, should be identical to its price in the United States; any difference would suggest that a currency is either overvalued or undervalued. However, if we look at the real market prices, as of July 2025, the cheapest Big Mac was found in Egypt, where it costs the equivalent of 2.57$, compared to 6.01$ in the U.S. This implies that the Egyptian pound is undervalued by 57.9% (The Economist, 2025). The most expensive Big Mac is instead found in Switzerland, with a U.S. dollar price of 8.94$, indicating that the Swiss franc is overvalued by 49.6%. In the Eurozone a Big Mac costs 6.95$, implying a 15.2% overvaluation of the euro against the U.S. dollar (The Economist, 2025). The Economist also introduced the GDP-adjusted index, which should address the criticism that average prices tend to be to be lower in poor countries due to lower labor costs. Based on this index, the Egyptian pound is still the most undervalued currency (-40.8%), whereas the most overvalued is the Uruguayan peso (+72%); when adjusting for GDP the euro results overvalued by 36.1%. As explained by The Economist: “PPP signals where exchange rates should be heading in the long run, but it says little about today’s equilibrium rate”. A better guide to the current fair value of a currency would be the relationship between prices and GDP per person (The Economist, 2025). Other more intuitive reasons explaining why PPP does not typically hold in the short term are that raw materials and inputs to produce identical goods are not always easily traded across countries. Firms often face transport costs, taxes, tariffs or nontariff barriers when importing or exporting goods. Furthermore, especially in the service industry, prices incorporate a high labor, as well as a propriety rental component. Both wages and property prices can vary significantly across geographic regions, leading to substantial price differences of similar goods or services (Taylor and Taylor, 2004). In an empirical study conducted by Engel and Rogers (1999) on price variations between goods in the United States and Canada it emerged that the distance between cities significantly explains a considerable amount of the price differential for similar goods, even within the same country. Additionally, they provided evidence that price differentials are considerably larger for two cities located across different countries compared to two equidistant cities within the same country. This phenomenon is defined as the "border effect". Their estimates suggest that crossing the national border increases the volatility of price differentials to the same degree as adding an extra 2,500 to 23,000 miles of distance between the cities (Engel and Rogers, 1999). To summarize and conclude our discussion about Purchasing Power Parity theorem, despite this theory suggests that currency fluctuations should not impact firm performance, since prices should naturally adjust to a level that offsets exchange rate fluctuations, in the real world exchange rate risk does exist, particularly in the short to medium term. As observed by Flood and Rose (1995), “over shorter periods, nominal exchange rates move substantially and prices do not, so real and nominal exchange rate volatilities in the short term are correlated almost one for one, and the Law of One Price for traded goods is often violated” (Flood and Rose, 1995). Several papers have also observed that the Law of One Price is “flagrantly and systematically violated by empirical data” (Dufey and Srinivasulu, 1983; Sarno and Taylor, 2002), and that, even if PPP holds in the long-run, firms with shorter planning horizons are directly exposed to exchange rate risk (Dufey and Srinivasulu, 1983). The underlying causes of deviations from Purchasing Power Parity are to be identified in:

- Nominal price rigidities, often referred to as price stickiness. Since prices of goods and services do not adjust immediately to changes in exchange rates (Taylor and Taylor, 2004), real exchange rates exhibit a short-term volatility which is much higher than price volatility, leading to potential firm exposure to currency risk.

- Interaction between monetary policies and price stickiness. Monetary shocks can generate high levels of exchange rate volatility due to the phenomenon of exchange rate overshooting. The concept of exchange rate "overshooting" (Dornbusch, 1976) describes a situation where, following a change in monetary policies (like a change in the money supply), the nominal exchange rate initially adjusts by more than its long-run equilibrium level, before gradually returning to that long-run level. As previously discussed, prices of goods and services are sticky, meaning that they do not adjust instantaneously to new economic conditions or monetary shocks (Taylor and Taylor, 2004; Engel and Rogers, 1999). For this reason, when a monetary shock occurs, financial markets react almost immediately, whereas goods markets adjust slowly. Because prices of goods and services do not change immediately to absorb the monetary shock, the nominal exchange rate must "overshoot" to maintain the short-run equilibrium in the asset markets (Taylor and Taylor, 2004). This rapid, exaggerated movement of the nominal exchange rate, combined with sticky domestic prices, causes large and persistent deviations from PPP (Taylor and Taylor, 2004; Sarno and Taylor, 2002). Essentially, the purchasing power of currencies diverges significantly in the short run because the exchange rate moves too much relative to price levels.
- Transaction costs and difficulties in international arbitrage. Costs such as shipping, tariffs, and fixed trading costs create a so-called "band of inaction" for the real exchange rate (Taylor and Taylor, 2004; Sarno and Taylor, 2002). Within this band, price differentials are not large enough to motivate arbitrage, leading to persistent deviations from LOP and PPP.

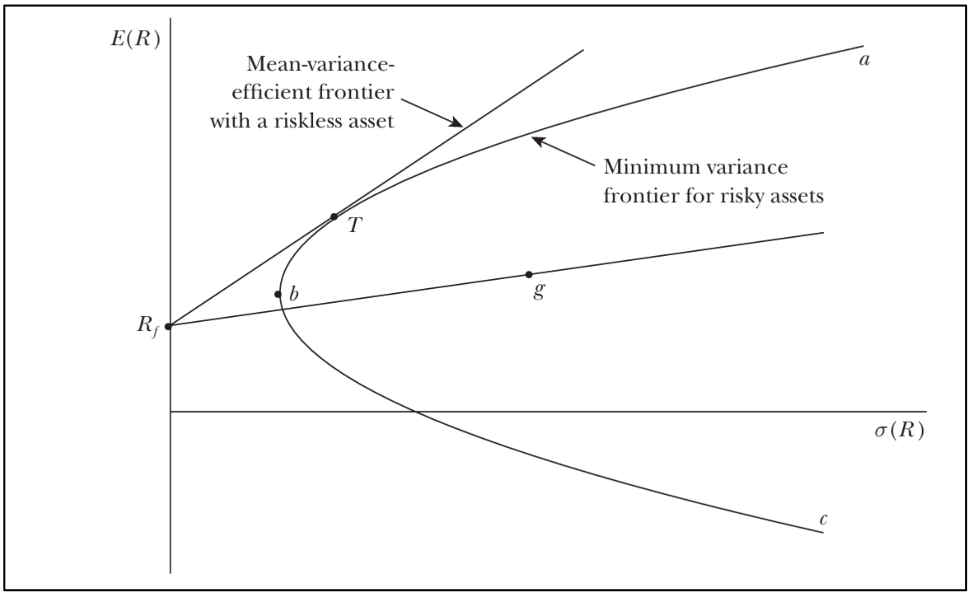
- Aggregation issues. PPP is often tested using aggregated price indices that might overlook underlying dynamics. Transaction costs vary across goods, and the weights of goods in price indices differ across countries. Also, many countries produce differentiated goods rather than perfectly substitutable ones, making a universal Law of One Price difficult to apply across all components of an aggregate index (Taylor and Taylor, 2004).
- Fluctuations in input and output prices within the same firm. Even if aggregate PPP holds at the level of a consumer price index (CPI), a firm's competitiveness can still be affected if the relative prices of its specific inputs and outputs vary due exchange rate changes (Adler and Dumas, 1984; Dufey and Srinivasulu, 1983).

For all the reasons mentioned above, while Purchasing Power Parity theory can act as a useful anchor to understand long-run real exchange rates equilibrium, it does not imply the absence of currency risk, especially when considering short to medium-term planning horizons and individual firms, rather than aggregate price indexes.

2.3.2 Capital Asset Pricing Model

The Capital Asset Pricing Model (CAPM), developed in the late 1950s and 1960s by William Sharpe, John Lintner, and Jack Treynor, building upon the portfolio choice model of Harry Markowitz, is a foundational theory in finance that aims to describe the relationship between risk and expected return for individual securities (Fama and French, 2004). According to Markowitz's model, investors are risk-averse and, when making portfolio decisions, focus solely on the mean and variance of their one-period investment return. Consequently, investors choose portfolios that either minimize risk, measured as return variance for a given expected return, or maximize expected return for a given variance. As explained by Fama and French (2004), the CAPM transforms this condition into a testable prediction by identifying a portfolio that must be efficient for asset prices to clear the market. The core principle of CAPM states that the expected return on any asset is linearly related to its systematic risk, and no other variable should have marginal explanatory power. CAPM is based on two key assumptions: first, we assume that all investors agree on the joint distribution on the assets, meaning that all investors have the same perception of expected returns, variances, and covariances of all assets available on the market. Not only do all investors agree on assets' risk and expected return, but they are perfectly informed, meaning that their shared beliefs perfectly reflect reality. Second, we assume that there is an unlimited ability to borrow and lend at a single, risk-free interest rate, which is the same for all investors, regardless of the amount (Fama and French, 2004). The figure below graphically describes the CAPM core concepts.

Figure 1: *Investment opportunities (Fama and French, 2004)*



On the horizontal axis we plot portfolio risk, expressed as the standard deviation of returns, while the vertical axis represents the portfolio expected return. The abc curve is defined as the minimum variance frontier and depicts the set of portfolios composed exclusively of risky assets that achieve the lowest possible variance for each level of expected return. Since risk-free borrowing and lending are not included here, the frontier illustrates the direct trade-off between risk and return: for instance, an investor aiming for a higher expected return, such as at point a, must also accept a higher degree of volatility. When adding the possibility of lending and borrowing a risk-free asset, the set of efficient portfolios becomes a straight line. The point R_f represents an investment portfolio where all funds are invested on the risk-free asset, while portfolios that combine risk-free lending or borrowing with some portion of the risky portfolio g are plotted along the straight line from R_f through g. The mean-variance-efficient portfolios when risk-free borrowing is available corresponds to the straight line starting from R_f which is tangent to the minimum variance frontier of risky assets. Building upon this knowledge we can now introduce the core idea of the Capital Asset Pricing Model, as effectively summarized by Fama and French (2004):

"With complete agreement about distributions of returns, all investors see the same opportunity set, and they combine the same risky tangency portfolio T with risk-free lending or borrowing. Since all investors hold the same portfolio T of risky assets, each risky asset's weight in the tangency portfolio, which we now call M (for the "market"), must be the total market value of all outstanding units of the asset divided by the total market value of all risky assets. In addition, the risk-free rate must be set (along with the prices of risky assets) to clear the market for risk-free borrowing and lending." (Fama and French, 2004).

In simpler words we can say that, when investors desire to combine a portfolio of risky assets with a riskless security, they must choose a point on the line connecting both assets, which in the diagram above corresponds to the line originating in R_f, tangent to the efficient frontier of risky assets. The best portfolio combination is achieved when the line reaches its highest possible slope. This line is then called the Capital Market Line (CML), and its slope is the so-called Sharpe ratio. The point where the CML encounters the efficient frontier gives the best portfolio of risky securities, which is the tangent portfolio T. Although different investors have different risk-return preferences, when a riskless security is available on the market, the Two-Fund Separation Theorem by Tobin (1958) affirms that agents should diversify between the risk-free asset and a single optimal portfolio of risky assets (Hens and Rieger, 2010). As previously seen, the Tangency Portfolio gives the optimal combination of risky assets; thus, "The striking conclusion of Markowitz' analysis is that all investors who care only about mean and standard deviation will hold the same portfolio of risky assets" (Campbell and Viceira, 2002). Consequently, the Tangency Portfolio is also defined as the Market Portfolio. Based on this formulation the traditional Sharpe-Lintner equation is derived, which directly describes the relationship between asset risk and return:

$$E(R)_i = R_f + \left[E(R_M) - R_f\right] \beta_{iM} \quad i = 1, \cdots, N.$$

Where $E(R)_i$ is the expected return on an asset i, R_f is the risk-free interest rate, β_{iM} is the asset's market beta, indicating how much the asset covaries with the market, and $\left[E(R_M) - R_f\right]$ is the market premium per unit of beta risk. In short, according to the Capital Asset Pricing Model, the expected return on any asset is equal to the risk-free rate plus the risk premium for the non-diversifiable risk, namely for the market risk (Vernimmen et al., 2014). This theory explains that "an investor's required rate of return is not linked to total risk but solely to market risk. In other words, in a fairly valued market, intrinsic, or diversifiable, risk is not remunerated" (Vernimmen et al., 2014). The relationship between risk and expected return for any individual security or portfolio in equilibrium is typically represented by the Security Market Line, which allows investors to understand whether an asset is fairly priced or whether it is overvalued versus undervalued. The link between the Capital Asset Pricing Model and foreign exchange risk management is to be identified in the idea that, according to CAPM, only one systematic risk factor matters, namely the covariance of an asset return with the market portfolio. If exchange risk is unsystematic, investors can diversify it away when constructing their portfolios (Dufey and Srinivasulu, 1983). On the other hand, even if exchange rate risk is systematic and if we assume that forward contracts are priced according to the CAPM, buying these contracts will simply allow firms to move along the Security Market Line, without adding any value to the firm (Dufey and Srinivasulu, 1983). Therefore, as summarized by Logue and Oldfield (1977):

"Modern portfolio theory suggests that the value of a firm is dependent only on its expected profitability and the systematic (i.e. investor non-diversifiable) risk of this profitability. When exchange rates vibrate randomly, some firms may gain, and others lose. Other things equal, the risk of such changes in real value are incorporated within existing security values. Hedging against exchange rate changes should not affect a firm's value when currency price changes are either systematic or unsystematic. Thus, within the context of simple portfolio theory, individual firms cannot systematically affect their share valuation by minimizing the influence of unpredictable future currency price fluctuations" (Logue and Oldfield, 1977).

In different words, Logue and Oldfield (1977) explain that, since foreign exchange markets are assumed to be efficient, meaning that current exchange rates already contain all relevant information, there is no "hidden" information that would allow investors to predict their future movements, generating profit opportunities. Let us consider the example of a multinational firm with a subsidiary abroad. The foreign subsidiary is exposed to currency fluctuations, but if these fluctuations are uncorrelated with the general stock market, taking measures to hedge away the exchange risk cannot change how the subsidiary's earnings move with the market. Hedging currency risk reduces the total volatility of a firm's value, but it solely impacts unsystematic risk; since investors can already eliminate unsystematic risk through diversification, the firm does not gain anything in terms of its expected value. For this reason, Logue and Oldfield (1977) affirm that trying to hedge against random, unexpected events, such as currency fluctuations, may be more costly than simply bearing the risk of these events.

The Capital Asset Pricing Model, despite providing a nice and simple rule for portfolio decisions, as well as to evaluate the "fair" price of an asset, it does not come without overly simplified assumptions and limitations that make its application in practical circumstances often problematic.

- First, similarly to the Purchasing Power Parity theory, the central assumption of CAPM is that markets need to be perfect for the model to hold. A perfect capital market is an idealized theoretical construct characterized by the absence of transaction costs, issuance costs associated with securities trading, costs of financial distress, agency problems, and information asymmetries. However, in the real-world capital markets these frictions are present and must be accounted for when making investment decisions. Thus, the presence of these market imperfections provides compelling economic rationales for firms to actively engage in foreign exchange risk management, moving beyond the theoretical irrelevance predicted by perfect capital market models (Dufey and Srinivasulu, 1983).
- Second, several empirical studies investigated the validity of the Security Market Line and concluded that market risk explains the excess returns of assets, but only to some extent. Additional factors, such as value, size and momentum of assets (Hens and Rieger, 2010), as well as firm earnings-price ratios, debt-equity ratios, and book-to-market equity ratios (Fama and French, 2004) are also necessary, to better explain stock returns. Furthermore, researchers often encounter obstacles in the empirical validation of this theoretical model. For instance, one major challenge is defining a truly comprehensive market portfolio, which should include all traded financial assets, consumer durables, real estate, and human capital, possibly on a global scale, making the true market portfolio impossible to replicate empirically (Fama and French, 2004).
- Lastly, when it comes to CAPM implications for corporate management of exchange risk, a crucial exception needs to be considered. As we previously mentioned, hedging exchange risk reduces the total variability of a company's cash flow, without affecting

systematic risk, and thus without altering the firm's stock value. However, total variability of a firm's cash flow is very much relevant for corporate management, since it directly impacts firm solvency. A high cash flow variability increases a firm's probability of bankruptcy, which in turn affects the firm's ability and costs of raising funds (Dufey and Srinivasulu, 1983). To quote Logue and Oldfield (1977): *"Creditors may be concerned with total variability of cash flows where default is possible. The realized yet unanticipated capital gains and losses that a firm experience due to random currency fluctuations may influence valuation through the effect on debt capacity. Where total variability is important, hedging in the foreign exchange markets may add to the firm's debt capacity* (Logue and Oldfield, 1977). Consequently, one of the main reasons justifying corporate management of currency risk is the desire to minimize a firm's default risk and to increase the company's debt capacity (Dufey and Srinivasulu, 1983).

2.3.3 Modigliani-Miller theorem

The last fundamental theorem that we will introduce in the context of corporate management of exchange risk is the Modigliani-Miller theory. The MM theorem, developed by Franco Modigliani and Merton Miller, introduces the fundamental principle in corporate finance that the total market value of a firm, its average cost of capital, and its capital budgeting decisions are independent of the firm's leverage (Modigliani and Miller, 1958). In other words, according to this theory, "different packaging of contractual claims on the firm's assets does not impact the total market value of the firm's debt and equity" (Charness and Neugebauer, 2019). For this "irrelevance theorem" to hold, capital markets should display specific conditions, such as being perfectly integrated, meaning that all investors are perfectly informed, there are no transaction costs, a fixed investment policy, no taxes, as well as no contracting costs. This theory is based on the core idea that if a firm tries to alter its value by modifying its financing structure, investors can perfectly replicate or undo these changes through their own personal financial decisions, often referred to as "homemade" financing adjustments. Consequently, in such an environment, the way a firm finances its operations, whether through debt or equity, does not create or destroy shareholder value (Smith and Stulz, 1985). The proof of the Modigliani-Miller theory is based on the idea of an arbitrage-free capital market. In a perfect capital market, if two assets, one leveraged and one unleveraged, represent claims on the same cash flows, any discrepancies in the market value of the assets are arbitraged away (Charness and Neugebauer, 2019). This concept extended to corporate management of exchange risk implies that, in the idealized world assumed by the Modigliani-Miller theorem, corporate hedging and investor hedging are perfect substitutes. If markets are perfect and investors can hedge foreign exchange risk on their own without incurring any extra costs, corporate hedging would not add any value (Dufey and Srinivasulu,1983). Let us assume for example that a U.S. company has exported some goods to Europe and expects to receive 1 million euros in one year to settle the payment. Today's spot exchange rate is 1 EUR = 1.10 USD, so the company expects to receive the equivalent of 1.1 million dollars in one year. Since the EUR / USD exchange rate in one year could vary significantly, the firm can enter into a one-year forward contract, promising to sell 1 million euros in exchange for 1.1 million dollars, effectively locking today's exchange rate for the future transaction. In perfect capital markets, if the firm decides to stay unhedged and bear the exchange rate risk, its market value will not change, since all rational investors that hold a share of the firm would hedge away this risk on their own. To shield themselves against currency risk, investors would offset their unhedged long position in the company by shorting a 1 million euros forward at 1.1 million dollars themselves. By doing so, investors would achieve a pay-off that is identical to what they would have received if the company took measures against currency risk. The MM arbitrage-free rationale allows us to demonstrate that two companies with the same cash flow, one hedged and one unhedged against exchange rate risk, must have the same market value. This happens because, in perfect capital markets, if the shares of a company that actively hedges against currency risk are priced higher than an unhedged company, investors would sell the (overpriced) shares of the hedged company, buy the (underpriced) shares of the unhedged one, and enter into a forward contract that protects them against currency risk on their own. Thus, we must conclude that, under perfect capital markets, the value of the firm is invariant to corporate foreign exchange hedging. As examined in the previous chapters, the notion of perfect capital markets remains a theoretical abstraction. In practice, financial markets deviate from the classical Modigliani–Miller framework in several ways. These deviations are at the basis of the reason why an active management of currency risk can provide concrete benefits for firms. The most significant of these deviations include:

- Taxes: Smith and Stulz (1985) provide an explanation of why the structure of the tax code can make it advantageous for firms to engage in hedging, including against currency risk. The central mechanism is that if a corporation's effective marginal tax rate increases with its pre-tax income, meaning that higher pre-tax values are subject to disproportionately higher taxation, then the after-tax value of the firm becomes a concave function of its pre-tax value. Formally, we can represent this relationship with following equation:

  $$V_{after-tax} = V_{pre-tax} - T(V_{pre-tax})$$

  where T represents the firm's tax liability. In this framework we see that tax payments increase non-linearly, since marginal tax rates rise with income. As a result, the after-tax value curve bends downward, implying that each additional unit of pre-tax income provides a decreasing marginal amount to the firm's after-tax value. Using a state-preference model, Smith and Stulz (1985) demonstrate that, if the cost of hedging remains sufficiently low, reducing the variability of pre-tax firm values through hedging, can lower the expected corporate tax burden, ultimately increasing the expected post-tax value of the firm. Thus, given that the benefits of hedging outweigh its costs, corporations have a clear incentive to mitigate exposure to unexpected currency fluctuations.

- The cost of financial distress: Firms may also choose to hedge against currency risk in order to lower the probability of incurring bankruptcy costs. Let us consider a firm that has issued debt with a face value F to finance its operations. At maturity, if the firm is solvent, bondholders are repaid in full (they receive exactly F), while shareholders receive the residual claim:

$$Shareholders'payoff = V_{firm} - F - taxes$$

  Conversely, if the firm's value is insufficient to cover its debt obligations, shareholders receive nothing, and bondholders receive a reduced payoff due to bankruptcy costs:

$$Bondholders'payoff = V_{firm} - bankruptcy\ costs$$

  In the event of default, these costs decrease the firm's value and diminish bondholders' claims. Consequently, by reducing the variability of its future value through effective management of exchange rate risk, a firm can lower the probability of default and the associated costs of financial distress, thereby generating benefits for both shareholders and bondholders (Smith and Stulz, 1985).
- Differences in hedging capabilities of firms versus individual investors: Modigliani and Miller argue that corporate hedging of exchange rate risk does not increase firm value, since individual investors can theoretically hedge such risk themselves, and any discrepancy in the valuation of hedged versus unhedged firms would be eliminated through arbitrage. However, as Dufey and Srinivasulu (1983) explain, if investors' hedging is less efficient than corporate hedging, it becomes advantageous for shareholders to delegate the management of exchange rate exposure to the firm. In

practice, firms possess better hedging capabilities than individual investors, who face significant size and structural barriers when it comes to hedging measures. These size-related barriers arise because many foreign exchange instruments, such as forward contracts, currency options, Eurocurrency markets, and foreign money markets, impose minimum transaction sizes that exceed the capacity of most individual investors. Futures and options markets can serve as alternatives for smaller transactions, but access to these markets is constrained: trading is limited to a small number of exchanges per day and investors must post margin deposits, which increase costs. Structural barriers, by contrast, arise from differences in institutional access and regulation. For example, foreign money markets often limit participation by nonresidents or impose discriminatory taxes, limiting individuals' ability to hedge through borrowing or lending foreign currencies. Multinational firms with local subsidiaries, however, do not face these restrictions and are therefore better positioned to obtain low-cost hedges. As Dufey and Srinivasulu (1983) conclude, firms are typically in a superior position to manage exchange risk relative to individual investors.

In summary, although some theories based on idealized market conditions argue against corporate foreign exchange risk management, the existence of real-world market imperfections, such as transaction costs, information costs, financial distress costs, and incomplete securities markets strongly support the case for corporate management of this risk. In the next section we will introduce a theoretical model which tries to formally integrate foreign exchange risk into the pricing of securities. We will then discuss its empirical validity and show how empirical tests of this model led to the emergence of the "foreign exchange exposure puzzle".

2.4 From the ICAPM to the FX Exposure Puzzle

The International Capital Asset Pricing Model (ICAPM) is an extension of the traditional Capital Asset Pricing Model (CAPM) that accounts for exchange rate risk as a significant factor in determining asset prices (Apergis et al., 2011). The theoretical background for this model is set by Solnik (1974), Adler and Dumas (1983) and Sercu (1980) and is based on the idea that, when Purchasing Power Parity is violated, investors from different countries face different prices of goods and services at which they consume their income. Consequently, they perceive the returns from the same assets differently, giving rise to distinct risk premia. To better explain this concept let us introduce the example of two investors located in two different countries: Japan and the United States. Japanese investors consume goods and services in yen, while Americans in U.S. dollars. Because of exchange rate fluctuations, the same financial return measured in dollars may not translate into the same real purchasing power for a Japanese or a U.S. investor. For instance, if a Japanese investor holds a U.S. stock which yields 5% in USD, but the yen strongly appreciates against the dollar, the investor's return might be much lower. On the other hand, in case the yen depreciates against the USD, investors' stock yields are boosted. For this reason, we expect investors to be willing to pay more for assets that covary with the domestic currency, which protects their domestic purchasing power (Dumas and Solnik, 1995). Investors across different countries might perceive the risk of the same asset very differently and therefore require different risk premia because of currency exposure. This idea is formalized in the ICAPM, where asset returns are not determined solely by market risk, but also by additional risk premia based on the covariances of assets with exchange rates (Apergis et al., 2011). The ICAPM as formulated by Adler and Dumas (1983) is represented by the following equation:

$$E\left[r_{jt}\middle|\Omega_{t-1}\right] = \sum_{i=1}^{L} \lambda_{i,t-1} cov\left[r_{jt,} r_{n+i,t} \vee \Omega_{t-1}\right] + \lambda_{m,t-1} cov\left[r_{jt}, r_{mt} \vee \Omega_{t-1}\right]$$

The left-hand side of the formula, $E[r_{jt}|\Omega_{t-1}]$, represents the expected excess return over the local risk-free rate on asset $j, j = 1 \cdots m$ between $t-1$ and t, conditional on information available at $t-1$. The right-hand side of the formula consists of the factors explaining the asset excess returns, which are:

- r_{mt}: the excess return on the world market portfolio
- Ω_{t-1}: the information set that investors use in choosing their portfolios at time $t-1$
- $r_{n+i,t}$: the innovations or shocks in the exchange rate, such as unexpected currency fluctuations
- $\lambda_{i,t-1}$, $i = 1 \cdots L$: time-varying world prices of exchange rate risk, indicating the extra expected return required by investors per unit of covariance with exchange rate risk factor i.
- $\lambda_{m,t-1}$: time-varying world price of market risk, indicating how much extra expected return investors demand per unit of covariance with the global market portfolio (similarly to the traditional CAPM).
- L: the number of independent exchange rate risk factors, where each factor corresponds to the fluctuation of one specific currency. For example, if we consider investors with four relevant home currencies, e.g., USD, EUR, JPY, and GBP, then $L = 3$, as we consider one currency at a time (e.g., USD) and we model the relative exchange rates to the other three currencies (Dumas and Solnik, 1995).

According to the ICAPM formulation, the nominal excess return on an asset or portfolio j is determined by both its covariance with the world market portoflio ($cov[r_{jt}, r_{mt} \vee \Omega_{t-1}]$), and its covariance with exchange rate fluctuations ($cov[r_{jt}, r_{n+i,t} \vee \Omega_{t-1}]$). Investors demand higher returns on assets that expose them to higher currency risk, whereas they accept lower returns if the asset contributes to hedging away the risk of unexpected currency movements.

We notice that the ICAPM equation aggregates several investor categories and their different perceptions based on their home currencies. As previously explained, since investors across different countries have access to goods at different prices, their perception of returns from the same assets also differs. By contrast, "the classic APM (CAPM) ignores investor diversity of that kind and assumes, in effect, that everyone in the world translates returns into consumption as do the residents of the reference currency country. Hence, no exchange-risk hedging premium appears" (Dumas and Solnik, 1995). The International Capital Asset Pricing Model (ICAPM) and its underlying theories have been tested by several researchers. These studies explicitly aim to determine if exchange rate risk is a priced factor in international asset markets. The conflicting results from empirical analyses of the model gave rise to what we have defined as the "foreign exchange exposure puzzle". Although the ICAPM clearly states that exchange rate risk is a priced factor in international asset markets, meaning that investors require compensation for bearing this additional risk (Dumas and Solnik, 1995), empirical studies often find weak or statistically insignificant evidence of this extra risk premium for a large percentage of firm stock returns (Bartram and Bodnar, 2007).

2.5 Hedging instruments for exchange rate risk management

In recent years, the specific hedging needs of the modern firm dramatically increased. As a result, nowadays there is an enormous body of hedging instruments available to firms to mitigate their exposure to currency risk (Hakala and Wystup, 2002; Shapiro, 1996). There are two main ways in which firms can mitigate the impact of currency fluctuations on their profitability: operational and financial hedging (Stulz, 1984). Operational hedging, also defined "natural hedging", consists in structuring a firm's operations so that its cash flows and profitability is naturally hedged against exposure to foreign currencies. Financial hedging, on the other hand, consists in offsetting a multinational company's exposure by using financial instruments like currency forwards, futures, options, and swaps (Bartram and Bodnar, 2007).

2.5.1 Operational hedging

According to most international finance textbooks, the first-best option against currency risk is to design a firm's operations trying to choose a mix of outputs, inputs, market segments, production locations and strategic financial decisions that minimize the net exposure to exchange rates (Bartram and Bodnar, 2007; Bradley and Moles, 2002). There are several ways in which firms can modify their operational structure and activities to mitigate exchange rate risk, the main ones being:

- Matching and netting: Where matching refers to the strategy of pairing foreign currency inflows and outflows (e.g., revenues and costs) of similar amounts and timing to reduce the net exposure (Papaioannou, 2006). Let us consider the example of an Italian car manufacturer expecting to receive 10 million dollars of export revenue from the United States. At the same time, the manufacturer must face a cost of 10 million dollars to buy car components from a U.S. supplier. In case the euro appreciates against the dollar, both revenues and costs decrease in value when converted to euros, but since they are of the same size and timing, the firm's net exposure to USD risk is close to zero. Netting, on the other hand, means to consolidate the settlement of receivables, payables, and debt among subsidiaries of a multinational company (Papaioannou, 2006). If several subsidiaries of the same company have issued debt to each other in different currencies, instead of repaying each debt separately, the multinational consolidates the flows and settles the debt with the minimum number of transactions possible. By doing so, both transaction costs and the firm's total exposure to exchange rate volatility are lower.
- Supply chain flexibility: In the last decades supply chain professionals have dedicated increasing attention to the impact of foreign exchange risk on supply chains and, particularly, to how a flexible supply chain design can contribute to FX risk mitigation. A supply chain can be flexible along different dimensions of its operations: production

flexibility refers to a firm's capability of switching production plants and locations in response to market opportunities or threats (Heydari et al., 2020), while sourcing flexibility consists in having a large supplier base among which a firm can easily switch according to its current needs. More generally, flexibility can also be realized through contracting strategies, which effectively contribute to "sharing or passing price volatility with suppliers" (Ogunranti et al., 2021; Pellegrino et al., 2022). What emerged from recent empirical studies is that the most frequently used flexibility strategies are sourcing flexibility and escalation clauses (Lu et al., 2018; Pérez Pérez et al., 2016; Zsidisin and Gaudenzi, 2018; Pellegrino et al., 2022). Pellegrino (2022) empirically investigated supply chain managers' mitigation strategies of currency risk, finding that typically a mix of strategies are adopted, such as sourcing and contractual flexibility, and often consolidating the inputs from various business functions like supply chain, marketing, finance, and treasury (Pellegrino et al., 2022). It has also emerged that, even though firms face initial sunk costs to create flexible supply chains, the managerial flexibility allowing to respond to unfavorable FX fluctuations by changing suppliers or enacting escalation clauses can positively affect a firm's financial performance. However, this effectiveness is case-dependent and contingent on environmental uncertainty, such as the degree of FX fluctuation, quantity uncertainty, or the length of time horizons (Pellegrino et al., 2022).

- Invoice currency choice: A very simple and direct method that firms can use to operationally hedge currency risk is to strategically choose the invoice currency. If a transaction is invoiced in the exporter's home currency, the importer bears the FX risk, while the exporter is protected. The opposite happens when the invoice is issued in the importer's domestic currency. Thus, using local-currency invoicing when exporting goods minimizes a firm's direct exposure to potential currency fluctuations. As shown in the paper by Ito et al. (2016) which analyzes FX risk hedging strategies of Japanese firms, exporting firms with a dominant share in the market intentionally choose yen invoicing, so that their performance is not affected in case the dollar depreciates against the yen. By contrast, companies exporting less competitive products and which can not insist on yen invoicing usually opt for alternative FX risk-mitigating strategies (Ito et al., 2016).

- Price revisions (pass-through) strategies: A firm can protect its cash flow from exchange rate fluctuations by adjusting the prices of its exported goods (Ito et al., 2016). The effectiveness of this strategy though depends on the firm's competitive position. Highly competitive firms with flexible demand can afford to revise their prices relatively frequently in response to exchange rate movements. By contrast, if customers are highly price-sensitive, frequent adjustments may reduce demand and lead to a loss of sales.

Operational hedging, while being the first-best option to shield a multinational company from exchange rate fluctuations, is very time-consuming and cost-intensive. Firms which had the foresight to build into their operational structure a certain degree of flexibility are able to respond operationally to FX fluctuations quickly, but making the desired operational changes starting from scratch usually take a substantial amount of time (Bartam and Bodnar, 2007). For instance, it can take a firm up to several years to move production locations or to alter its output mix (Bartam and Bodnar, 2007). In a study by Holland (1992) covering 14 internationally involved UK companies it emerged that, despite many firms have a certain degree of freedom when formulating and revising production, financing, as well as marketing decisions, most of the firms opt for inflexible operational strategies, in order to benefit from market competitive and comparative advantages. Additional factors that limit the feasibility of operational hedging include the advantages of economies of scale in production and distribution, as well as the transaction costs associated with altering a firm's operations (Dolde, 1993). Thus, many practitioners argue that operational hedging is particularly valuable when applied to longer-term, difficult-to-predict currency cash flows (Holland, 1992; Bradley and Moles, 2002), but that it is less suitable to respond quickly to short-term fluctuations in exchange rates.

2.5.2 Financial hedging

While operational hedging methods are used to hedge away currency risk in the long run, firms predominantly use financial hedging, and especially financial currency derivatives, to shield themselves from short-term exposures (Bartram and Bodnar, 2007). The primary goal of exchange risk hedging through financial instruments is to minimize the variability of cash flow and accounting earnings, since these factors play a fundamental role in the perception and prediction of future earnings, as well as in the determination of managers' compensation (Papaioannou, 2006). Financial hedging includes both over-the-counter instruments, such as currency forwards and cross-currency swaps, as well as exchange-traded instruments, like currency futures and option contracts. We will now proceed to briefly introduce each instrument and its main application scope.

- Currency forwards are contracts in which two parties agree to buy and sell a currency at a future date at a predetermined rate. These contracts include outright forwards, which require the physical delivery of currencies at maturity, and non-deliverable forwards, which are settled on a net cash basis. While forwards provide complete hedging, they can be costly and may expose firms to adverse rate movements (Papaioannou, 2006). For example, suppose a Chinese company expects to receive a payment of 10 million USD in six months, which needs to be converted into RMB. Since the RMB is currently appreciating, the company is concerned that a depreciation of the U.S. dollar will reduce the RMB value of its payment. To protect itself, the company signs a six-month forward contract with the Industrial and Commercial Bank of China to sell its future 10 million dollars at a fixed rate of RMB/USD = 6.56. If the company’s expectation is correct and the RMB does appreciate, reaching a spot rate of RMB/USD = 6.40 after six months, the company will convert its payment into 65.6 million RMB. By contrast, without hedging, it would receive only 64 million RMB. Alternatively, if the RMB depreciates and the spot exchange rate after six months is RMB/USD = 6.60, the company must still convert its payment at the contracted rate, receiving 65.6 million RMB. In this case, it would have received 66 million RMB without the hedge. Thus, short hedging does not necessarily guarantee additional profit; rather, it locks in the selling price and thereby eliminates currency risk.

- Cross-currency swaps are foreign exchange contract agreements that allow two parties to exchange principal and interest rate streams in two different currencies. Cross-currency swaps are particularly well-suited to protect an organization’s long-term positions against currency risks, especially in the case of loans or bonds floating in foreign currency. This instrument is specifically designed for the management of long-term, multiple-period foreign currency exposures, such as the net worth of foreign subsidiaries. Compared to currency forwards, which typically have shorter maturities, currency swaps simplify the risk management of long-term positions and reduce basis risk through a reduction in the duration differential between the hedge and the exposure (Clark and Judge, 2009). Swaps can be structured to provide more preferable interest rates and to level cash flow fluctuations by exchanging fixed-rate for floating-rate payments, or vice versa (Papaioannou, 2006). Firms use currency swaps to transform the currency mix of their debt portfolio more flexibly, without necessarily incurring the expense of changing underlying transactions, like redeeming existing debt or issuing new debt (Clark and Judge, 2009). Moreover, cross-currency swaps can substitute or complement direct issuance of foreign currency debt in hedging strategies. For instance, firms can create "synthetic foreign debt" by swapping domestic debt into foreign debt, or "synthetic domestic debt" by swapping foreign debt into domestic debt (Clark and Judge, 2009). Among the various types of cross-currency swaps, the two most widely applied are the coupon swap and the basis swap. In a cross-currency coupon swap, one party agrees to pay a fixed interest rate in one currency while receiving a floating rate in another. For example, let us consider the case of a European firm with 100 million USD-denominated debt at a floating rate, but with revenues mostly denominated in euros. To match its debt and revenues, thereby mitigating its exposure to currency risk, the firm can enter a cross-currency coupon swap with a financial intermediary at the spot exchange rate of EUR / USD = 1,10. By doing this, the firm receives 100 million USD at floating exchange rate, while paying 90,91 million EUR at a fixed interest rate, effectively converting its USD floating-rate debt into EUR fixed-rate debt. This structure enables firms to simultaneously address both exchange rate and interest rate exposures (Papaioannou, 2006). By contrast, in a cross-currency basis swap, the interest rate payment is not transformed. An exemplary case would be a European bank funded primarily in EUR but in need of USD liquidity to be able to lend in U.S. dollars. The bank can enter a cross-currency basis swap (for the sake of simplicity, we will assume the same spot exchange rate as above), pays 90,91 million EUR, while receiving 100 million USD, both at floating exchange rates. This allows the bank to create synthetic USD funding, without changing its capital structure. Although this instrument carries the same currency risk as a conventional currency swap, it provides firms with the opportunity to benefit from differences in interest rate levels across currencies. The downside is that, in this case, the dominant source of risk stems from interest rate fluctuations rather than from exchange rate movements (Papaioannou, 2006).

- Currency options are a type of financial derivative traded on the exchange rate that grants a firm the right, but not the obligation, to purchase or sell a specified amount of a particular foreign currency at a predetermined strike price on or before a specific maturity date (Jorion, 1990). Currency options represent flexible tools without obligation to exercise, meaning that the buyer can decide to forfeit the option in case the exchange rate movement was unfavorable. Several types of option structures are available on the market, the most common one being the plain vanilla call, which consists in buying an upside strike in an exchange rate with no obligation to exercise (Sarno et al., 2003). The main advantages of option contracts include their simplicity, lower cost compared to forwards, and the predicted maximum loss, which corresponds to the premium.
- Currency futures, on the other hand, are very similar to forward contracts, with the main difference of being standardized and traded on exchanges. Unlike forwards, futures are more liquid and allow an easy exit before maturity if, for example, a firm decides before the settlement date that it no longer wants the position held. In the forward market, the size of the contract and the delivery date are tailored to individual needs, for instance they are determined between a firm and a bank, as opposed to currency futures contracts that are standardized and guaranteed by organized exchanges. Unlike forward contracts, most futures contracts are settled by offset and only very few by actual delivery. Furthermore, the price of a futures contract changes over time to reflect the market's anticipation of the future spot rate (Papaioannou, 2006).

Empirical studies show that most firms typically implement a hybrid approach, combining both financial and operational hedging. Allayannis et al. (2001) investigated whether financial and operational hedging strategies combined together can create shareholder value and found that operational hedging strategies alone are not significantly related to increased firm value.

However, when used in combination with financial hedging, operational hedges significantly increase firm value, measured as market-to-book ratio (Allayannis et al., 2001). Bartam, Brown, and Minton (2010) were able to quantify the benefits of foreign exchange hedging practices by analyzing the discrepancy between foreign exchange exposures as predicted in theoretical models with those measured utilizing empirical data. In their paper, they analyzed 1150 non-financial firms from 16 countries and found that exchange rate pass-through, as well as operational hedging can reduce firms' exposure by 10-15%, whereas financial hedging can further decrease exposure by 37-43% compared to a hypothetical firm that cannot mitigate exposure at all (Bartam et al., 2010). According to this paper, exchange risk management overall can reduce up to 70% of a firm's exposure to unexpected currency movements. In conclusion, foreign exchange risk management is characterized by a sophisticated and diverse array of instruments and strategies which reflect the complex nature of currency exposures that firms face in their day-to-day operations. This array of instruments includes traditional "physical" products like spot and forward exchange contracts, as well as "synthetic" or derivative instruments such as options, futures, and currency swaps (Batten et al., 1993). Often, foreign currency-denominated debt is also used as a hedging tool. Firms strategically select the most adequate instrument based on the nature of the exposure: short-term derivatives like forwards and options are typically used for transactional risks and uncertain cash flows, while longer-term instruments such as currency swaps and foreign currency debt are more suited for managing sustained exposures arising from foreign assets or liabilities (Papaioannou, 2006). The most effective approach frequently involves hybrid strategies, integrating financial hedging with operational hedging like the diversification of sourcing and production, or matching costs and revenues in the same currencies (Allayannis et al., 2001). This comprehensive, multi-layered approach allows firms to minimize cash flow volatility, reduce the probability of financial distress, and protect their value overall, while operating within an environment shaped by market imperfections such as transaction costs and information asymmetry.

3. Methodology

To test the relationship between exchange rate fluctuations and excess stock returns we replicate the methodology implemented by Tai (2024), which employs a Multivariate Generalized Autoregressive Conditional Heteroskedasticity (MGARCH) procedure to estimate an asymmetric three-factor exposure model. Previous studies trying to model exchange rate exposure by applying the Ordinary Least Squares (OLS) method were assuming excess returns to have constant variance. However, it has been observed that both firm excess returns and exchange rates show conditional heteroskedastic error terms. This implies that the variances (volatility) of excess returns and exchange rates are not constant over time, but instead they change conditionally to past information. The resulting phenomenon is what in econometrics is commonly referred to as volatility clustering, consisting in periods of high volatility typically clustered together, followed by periods of relatively low volatility. Conditional heteroskedasticity recognizes that the "noise" or uncertainty in a time series is dependent on events in the recent past rather than being random. The MGARCH model chosen by Tai (2024) for the estimation explicitly accounts for conditional heteroskedasticity by modelling the excess returns using a variance-covariance matrix which evolves over time, allowing to capture the effect of the different regressors on the dependent variable more accurately. To inspect whether the MGARCH methodology achieves better results compared to simpler methodological approaches, we estimate the three-factor exposure model first by OLS, then by univariate GARCH, which also serves as a diagnostic step to check our time series behavior, and finally by MGARCH, accounting for co-movements not only within, but also across time series.

3.1 Model and parametrization

The excess return of industry i in country j at time t $(r_{ij,t})$ is estimated by a three-factor model, similarly to Choi and Prasad (1995), where the excess return is described through a linear function of world market risk factor ($r_{w,t}$), interest rate risk factor ($r_{I,t}$), and currency risk factor ($r_{jc,t}$).

$$r_{ij,t} = \beta_{ijw} r_{w,t} + \beta_{ijI} r_{I,t} + \beta_{ijc} r_{jc,t} + \varepsilon_{ij,t} \quad \forall j = 1 \cdots N$$

In the model equation, β_{ijw} , β_{ijI}, and β_{ijc} are respectively the world market risk, interest rate risk and currency risk exposure coefficients. The interpretation of the symmetric and asymmetric exposure coefficients is highly dependent on the exchange rate quotation chosen. As the U.S. dollar is the dominant currency in global exchange markets, it is a common convention to quote the USD exchange rate directly, using the USD as the base currency. However, since we consider the exchange rate from the perspective of the euro as the domestic currency, USD/EUR is in our case an indirect quotation, which expresses how many units of EUR can be purchased with one unit of USD. For example, if the USD/EUR exchange rate is equal to 0.85, this means that 1 unit of USD can be exchanged with 0.85 units of EUR. When this ratio increases, one unit of dollar can purchase more units of euro, which implies that the euro is depreciating vis-à-vis the U.S. dollar. On the other hand, when the indirect quotation decreases, the euro appreciates against the dollar. In our time series we computed the currency risk ($r_{jc,t}$) as the log change in the bilateral USD/EUR currency exchange rates. In this context, a positive log change implies that the USD/EUR quotation is increasing and thus that the euro is depreciating, whereas a negative log change indicates an appreciation of the euro. Therefore, a positive β_{ijc} indicates that when $r_{jc,t}$ is increasing (positive log change in USD/EUR, which corresponds to euro depreciation), the excess-return of European countries and industries increases as well. Conversely, a negative β_{ijc} implies that, when the euro depreciates, equity market returns also decrease. Most studies investigating the impact of currency fluctuations on firm value assume that firms react symmetrically to domestic currency appreciation and depreciation, meaning that the sensitivity of a firm's value to exchange rate changes is uniform across appreciation and depreciation cycles (Koutmos and Martin, 2003). "Symmetric" here refers to the idea that the exposure magnitude does not change between appreciations and depreciations, but that it simply flips signs. However, Tai (2024), as well as Koutmos and Martin (2003) observe that firms might respond differently to currency appreciations as opposed to depreciations, due to several market mechanisms, such as Pricing-to-Market (PTM), hysteretic behaviors, and asymmetric hedging (Koutmos and Martin, 2003). PTM consists in changing the prices according to the level of competitiveness of foreign markets. As further argued by Knetter (1994), when firms are worried about mantaining or expanding their market share abroad, they might decide not to increase or even lower their prices despite unfavorable currency movements. For example, exporting firms facing a period of domestic currency appreciation, which typically threatens their competitiveness, might decide not to pass the adverse effects of appreciation onto their customers, to avoid potential losses in their sales volume and thus market share (Koutmos and Martin, 2003). Another potential source of asymmetries in a firm's exposure to currency risk is the so-called hysteretic behavior. Hysteresis refers to the idea that an effect persists even after the cause of the effect no longer exists (Koutmos and Martin, 2003). In the context of trade and exchange rate firms might display a hysteretic behavior if they decide to enter the market due to more favorable exchange rates, and do not exit the market when the currency is unfavorable. For instance, a depreciation of the domestic currency might attract new export-led firms, which might decide to enter the market. However, if the currency starts appreciating again, new market entrants typically do not exit the market immediately due to the high sunk costs faced at market entrance. Thus, when the domestic currency appreciates, existing exporters should see increased revenues, however their margins are compressed by new competitors. On the other hand, when the domestic currency appreciates, firm cash flow falls even more sharply, since new market entrants do not leave the market. Finally, Koutmos and Martin argue that currency hedging is inherently asymmetric, since it limits losses during periods of adverse currency movements, while leaving the potential benefits unlimited (Koutmos and Martin, 2003). Firm with stronger import orientation, might be inclined to hedge heavily against currency depreciation, which represents a threat to their foreign-currency payables, while remaining unhedged against euro appreciation. This asymmetric hedging behavior will ultimately generate an asymmetric impact on cash flows, as well as on stock returns (Koutmos and Martin, 2003).

Given all the reasons mentioned above, several studies suggest modelling the potential asymmetric component of exchange rate exposure by including a dummy variable D_t which assumes value 1 when the domestic currency is appreciating, and zero otherwise, as shown in the equation below. In our model, a euro appreciation corresponds to a negative log change in our bilateral USD/EUR exchange rate time series; thus, our dummy variable assumes value 1 whenever $r_{jc,t} < 0$.

$$r_{ij,t} = \beta_{ijw} r_{w,t} + \beta_{ijI} r_{I,t} + (\beta_{ijc} + \beta_{ijc}^{d} D_t) r_{jc,t} + \varepsilon_{ij,t} \quad \forall j = 1 \cdots N$$

If we rewrite the equation as follows:

$$r_{ij,t} = \beta_{ijw} r_{w,t} + \beta_{ijI} r_{I,t} + \beta_{ijc} r_{jc,t} + \beta_{ijc}^{d} (D_t \, r_{jc,t}) + \varepsilon_{ij,t} \quad \forall j = 1 \cdots N$$

we can see the currency exposure term decomposed into a "base" exposure ($\beta_{ijc} r_{jc,t}$), which corresponds to periods of euro depreciation, and an alternative or asymmetric exposure term ($\beta_{ijc}^{d} (D_t \, r_{jc,t})$) which estimates the additional exposure during periods of euro appreciation. The parameter β_{ijc}^{d} represents the variation in the intensity of currency exposure between appreciation versus depreciation phases. The sum of the β_{ijc} and β_{ijc}^{d} coefficients measures the full elasticity of stock returns observed under the regime where both the symmetric and asymmetric mechanism operate, namely during appreciation periods.

The univariate GARCH model is calculated for each series of country-industry excess returns, directly accounting for conditional heteroskedasticity in the error term, which is captured by including both an ARCH and GARCH effect in the variance equation. In our preliminary analysis we are implementing a GARCH (1,1), with only one ARCH and one GARCH term. The mean equation is the three-factor exposure model proposed by Tai:

$$r_{ij,t} = \beta_{ijw} r_{w,t} + \beta_{ijI} r_{I,t} + (\beta_{ijc} + \beta_{ijc}^{d} D_t) r_{jc,t} + \varepsilon_{ij,t} \quad \forall j = 1 \cdots N$$

where the error term is written as:

$$\varepsilon_{ij,t} = \sqrt{h_{ij,t}}\, z_{ij,t} \text{ with } z_{ij,t} \sim i.i.d.(0,1)$$

whereas the variance equation can be written as follows:

$$h_t = \omega + \alpha \varepsilon_{t-1}^2 + \beta h_{t-1}$$

In the variance equation, h_t is the conditional variance at time t, ω captures the long-run average variance, $\alpha \varepsilon_{t-1}^2$ represents the ARCH effect, and βh_{t-1} the GARCH effect. The ARCH term consists of the squared residuals of the previous period, measuring the shock intensity (large positive or negative deviations in the returns imply a bigger shock) and the α coefficient, measuring how strongly today's volatility reacts to that shock. The GARCH term measures how past variance (h_{t-1}) affects current variance. The sum $\alpha + \beta$ of the coefficient measures must be less than one for the model to be well-behaved, namely to ensure covariance stationarity and finite unconditional variance keeping volatility from blowing up. We can observe that the conditional variance (h_t) varies over time, depending on past squared residuals (ε_{t-1}^2). A large return movement yesterday increases $\varepsilon_{t-1}^2$and therefore today's volatility. This implies that a large shock tends to be followed by another large shock, correctly modelling the volatility clustering behavior, typical of financial data (Orskaug, 2009).

As for the multivariate GARCH (MGARCH) process, due to technical limitations in the statistical estimation of the model in R-studio, the parametrization and estimation procedure implemented in this thesis slightly differs from the methodology followed by Tai (2024). While Tai realizes a Diagonal MGARCH model as proposed by Ding and Engle (1994), in this thesis a Dynamic Conditional Correlation (DCC) GARCH estimation with Student-t errors is implemented. In the model realized by Tai (2024) all variances and covariances are modeled directly, by estimating each system of time series jointly. Conversely, the estimation process according to the DCC-GARCH includes two steps: the first step accounts for the conditional heteroskedasticity and consists in estimating, for each one of the series of returns, its conditional volatility using an univariate GARCH model. In the second step, the correlations between the different series of returns are modelled dynamically. This decoupled estimation procedure makes the DCC-GARCH more computationally efficient while still providing accurate results. The MGARCH step is necessary because financial volatilities across assets and markets often move together, making it crucial to account for the dependence in their co-movements (Orskaug, 2009). We choose the DCC-GARCH with Student-t errors, since it often provides a better fit for financial data compared to the DCC-GARCH with Gaussian-distributed errors (Orskaug, 2009).

3.2 Data collection

As introduced earlier, the empirical analysis presented in this thesis investigates the exchange rate exposure of European industries. The sample includes four countries, Germany and France, representing large economies, and Italy and Spain, representing smaller ones. Within each country, four industries were selected, according to the FTSE index sector breakdown: Telecom, Financials, Consumer Discretionary, and Utilities. The FTSE Consumer Discretionary index includes a variety of companies whose products and services are not essential, for instance retail, automotive, media, and leisure sectors. The selection of countries and industries was determined by data availability and consistency. Specifically, industries not present across the whole country sample were excluded, and all time series with missing observations were removed. The final dataset consists of complete weekly observations spanning from 30/03/2001 to 05/09/2025, yielding 1,276 time points per country–industry return series. All data were sourced from Datastream, the details of the extraction and computation procedures are summarized in the table below.

Table 1: *Summary of model data and extraction procedure*

Data	Extraction and calculation
Country-industry excess returns	Log first difference of the FTSE total return index (adjusted for dividends) for each industry in each country, minus the 1-week European Banking Federation Euribor rate.
World market risk	Log return of the MCSI all world index (expressed in euros), minus the 1-week European Banking Federation Euribor rate.
Interest rate risk	Log return of the European Monetary Union 10-years government bond total return index, minus the 1-week European Banking Federation Euribor rate.
Currency risk	Log changes in bilateral USD/EUR currency exchange rates.

In two specific cases, Germany–Utilities and Italy–Consumer Discretionary, the country-industry total return index series required data adjustments to ensure consistency over time. Both FTSE time series exhibited abrupt shifts, either upward or downward, that were not economically justifiable. These anomalies are likely the result of a rebasing operation performed by Datastream. To normalize the time series, after the computation of excess returns from the total return indices, the corresponding outlier observations were corrected by linearly interpolating the preceding and subsequent data points.

3.3 Data description

Before diving into the empirical analysis, we provide an overview of the sample data characteristics and check whether they align with the general properties of financial data.

Table A.1 (see appendix) reports the descriptive statistics of excess returns for the four European countries and four selected industries over the sample period. On average, we can observe that the mean excess returns are close to zero across all country-industry pairs. This is consistent with the properties of financial return series, where expected returns are small relative to their volatility. Standard deviations range between approximately 3% and 4.5%, indicating moderate dispersion in weekly returns, with Financials displaying higher volatility than other industries, such as Consumer Discretionary or Utilities. All series exhibit negative skewness, suggesting that most returns are small and positive, but that they occasionally experience sharp drops, a common pattern in equity markets. Kurtosis values are significantly above 3 for all series, implying heavy tails and a higher probability of extreme outcomes compared to a normal distribution. This leptokurtic behavior confirms the presence of volatility clustering, meaning that the returns show periods of high volatility alternated to periods of lower volatility. This behavior justifies the use of GARCH-type models in our subsequent analysis. Across countries, Spanish industries tend to display slightly lower volatility and milder skewness, whereas French and Italian Utilities exhibit the most pronounced leptokurtosis (above 12), reflecting occasional large price movements. We can also observe that all excess return series show two particularly sharp drops: the first one between 2008 and 2009, during the global financial crisis, and the second one during the years ranging from 2019 to 2021, corresponding to the Covid-19 crisis.

Table A.2 (see appendix) summarizes the descriptive statistics of the model risk factors. Similarly to excess returns, all risk factors' mean is close to zero. Volatility differs across the three factors, with world market risk showing the highest volatility (2.35%), currency risk showing moderate dispersion (1.25%), while interest rate risk exhibits the lowest level of volatility (0.85%). Both interest rate and world market risk factors are negatively skewed, indicating that large negative returns occur more frequently than positive ones. The opposite applies to currency risk, which shows positive skewness. This stems from the indirect quotation of the USD/EUR exchange rate in the currency risk time series. In this context, positive returns indicate that, to by 1 dollar, a higher amount of euros is needed, which implies that the euro is depreciating. On the contrary, negative returns imply a euro appreciation vis-à-vis the US dollar. Thus, the positive skewness of the currency risk factor indicates that large depreciations of the euro are more frequent than appreciations. All factors display leptokurtic behavior; the kurtosis of 9.63 for world market risk is particularly high, confirming the presence of heavy tails and volatility clustering, typical of stock market returns. The descriptive statistics of the three risk factors further support the use of statistical models which directly account for conditional heteroskedasticity like GARCH and MGARCH.

Figure 2: *Excess returns of German industries*

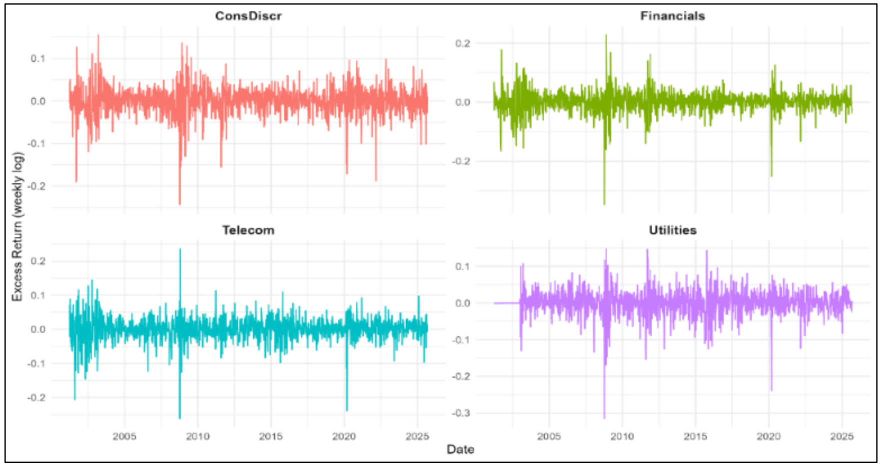


Figure 3: *Excess returns of Italian industries*

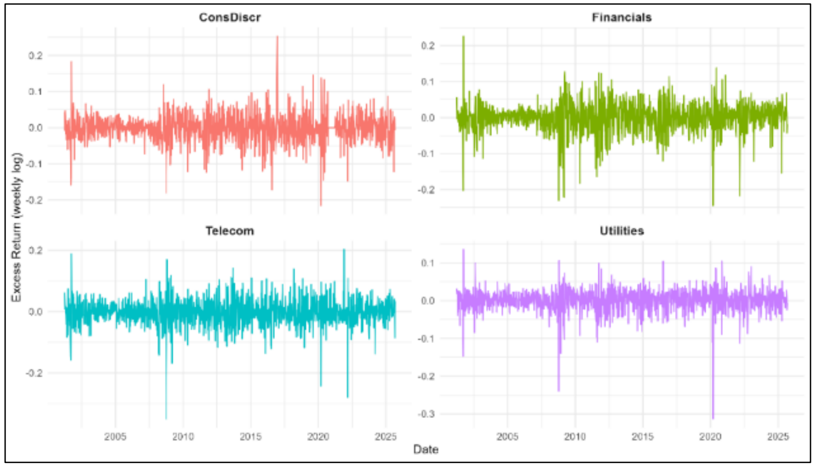


Figure 4: *Excess returns of French industries*

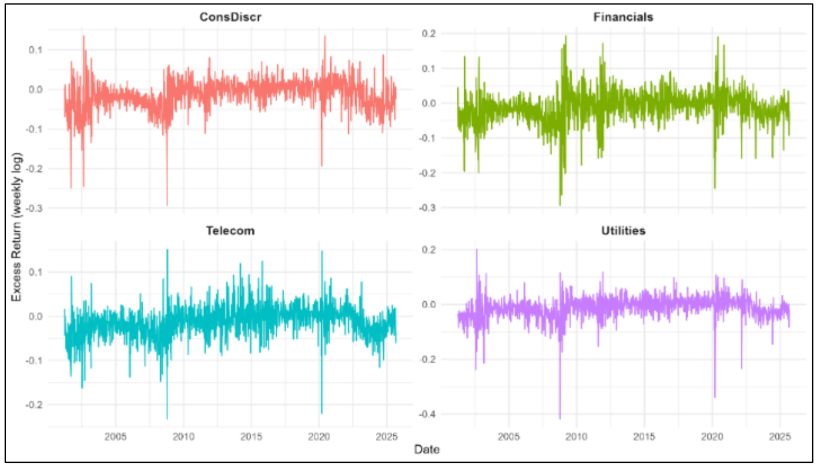


Figure 5: *Excess returns of Spanish industries*

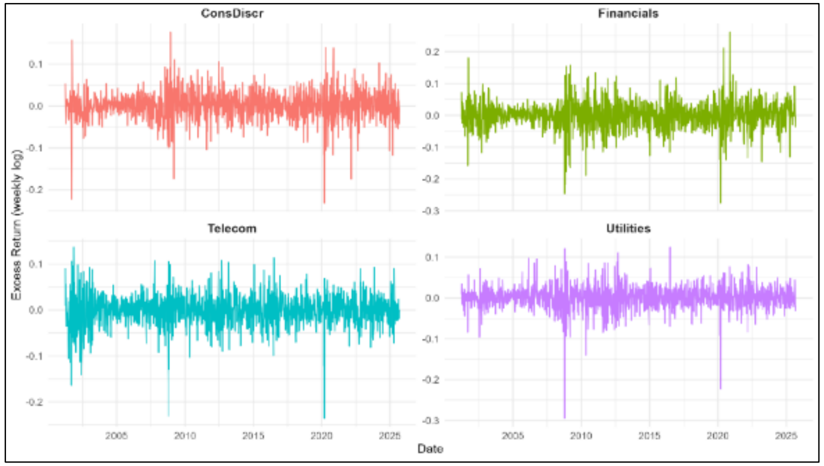


Figure 6: *Currency risk - Log changes in bilateral USD/EUR currency exchange rates*

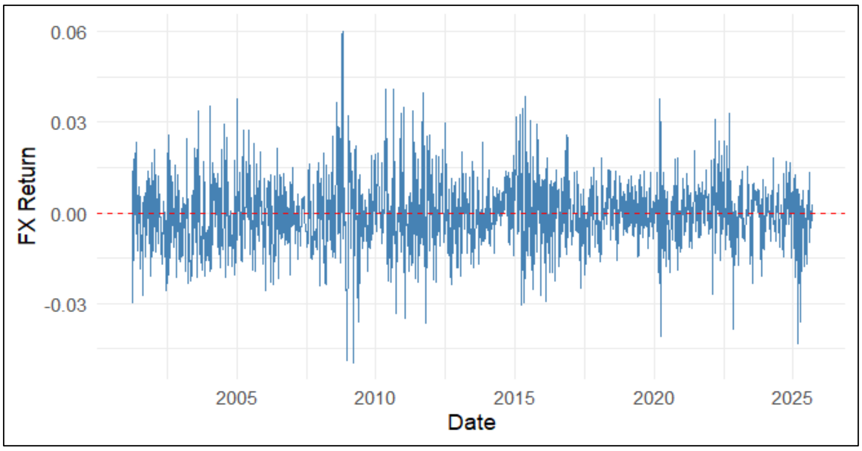


Figure 7: *Interest rate risk - Excess return of the EMU 10-years government bond total return index*

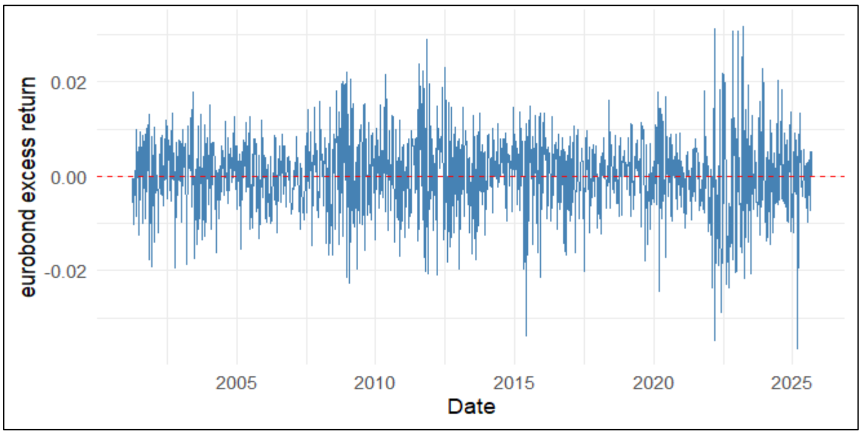
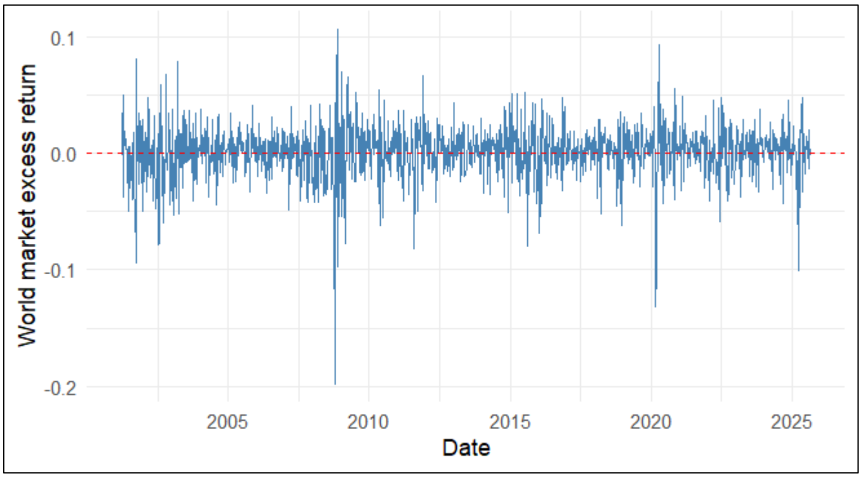


Figure 8: *World market risk - Excess return of MCSI all world index*



4. Empirical analysis

4.1 Preliminary analysis

After checking the general data properties and confirming the suitability of the chosen estimation methodology for our data, we perform a two-step preliminary analysis consisting of an OLS regression and subsequently a univariate GARCH. The results will be used as a baseline for comparison with the MGARCH model estimation.

Tables A.3, A.4, and A.5 (see appendix) summarize the baseline OLS estimates of the three-factor exposure model for all industries and countries. From this first analysis we can observe that:

- World market risk (β_{iw}) betas are positive and highly significant in all regressions, confirming that excess industry returns are strongly driven by global dynamics in equity markets, as well as general macroeconomic conditions. Coefficients range between 0.7 and 1.4**,** with the largest exposures observed in the financial sector**,** suggesting that financial industries are the most sensitive to global shocks.
- The interest rate risk factor (β_{iI}) is on average negative (–0.39), particularly for the Financials and Consumer Discretionary industries, but significant in only 50% of the cases, which signals a moderate exposure of country-industry returns to interest rate movements. The negative impact of β_{iI} indicates that an increase in bond prices, corresponding to a decline in yields, is generally associated with lower country-industry excess return. This is consistent with standard asset pricing intuitions, according to which falling yields tend to signal a period of market stress or risk aversion which encourages investors to switch from risky to safer securities.
- The β_{iC} coefficients are all negative and statistically significant in 15 out of 16 regressions. The only non-significant result has been found in the German Telecom

sector. The results suggest that a depreciation of the EUR relative to the USD tends to reduce excess returns for European industries. On the industry level, Financials show the strongest average exposure to currency depreciations (-1.02), followed by Utilities (-0.78), Consumer Discretionary (-0.51), and Telecom (-0.48). On the country level, exposures show high levels of consistency, with exception for Germany, showing on average a slightly stronger exposure to euro depreciations (-0.66) compared to the remaining sample countries.

- The differential term β_{iC}^{d} is positive in 13 out of 16 regressions, which would suggest a reduction in the exposure magnitude under euro appreciation, but shows very weak statistical significance. Sectors showing significant asymmetric currency exposure are Utilities in two of the four countries (France and Spain), and Telecom (only in France). This suggests that the intensity of exchange rate exposure in European industries does not change systematically in case of euro appreciation, and therefore we can assume the stock returns move linearly with changes in the exchange rate.
- The total exposure (β_{iC} $+\beta_{iC}^{d}$) averages -0.46 across all industries but given the limited significance of the asymmetric exposure term, we consider solely the base exposure coefficient, which amounts to -0.70 under depreciation and +0.70 under appreciation.

In terms of explanatory power of the OLS model, the R^2 values range between 0.23 and 0.62, indicating a moderate to high degree of fit. The highest R^2 values are found in the Financials and Consumer Discretionary sectors, suggesting that the model explains a substantial portion of return variability for industries more integrated into global markets. Conversely, Telecommunications and Utilities exhibit the lowest R^2, potentially due to their strong orientation towards national markets. A detailed interpretation of the OLS results goes beyond the scope of the analysis, which should serve as a reference point to evaluate the goodness-of-fit of the MGARCH model. For a deeper insight into the meaning of the model coefficients, see the MGARCH results interpretation. What is worth noting at this stage is that, contrary to the results reported in Tai (2024), the currency-exposure coefficients estimated via OLS already display a very high degree of statistical significance, whereas the asymmetric term is significant in only 12.5% of cases. This strong significance is driven primarily by the composition of the sample. The European focus makes the dataset more homogeneous and economically integrated than Tai's 12-country sample, which included emerging markets as well. Moreover, European industries tend to share common patterns of exposure to USD movements: all four sample countries are export-oriented in the Consumer Discretionary sector, while they are strongly import-oriented in the Utilities sector, except for France. Moreover, all four European countries exchange financial services with the United States and are inherently exposed to exchange-rate movements through their holdings of USD-denominated assets and liabilities. Finally, unlike Tai's cross-regional sample, where opposing regional effects may cancel each other out, the narrower sample and strong cross-country similarities reinforce directionality and consequently significance of the currency risk factor. In the next step of the preliminary analysis, we gradually increase the complexity of the estimation model by explicitly addressing the heteroskedasticity of the error terms. To this end, we re-estimate the same three-factor exposure model using a univariate GARCH specification. The resulting model coefficients are reported in the appendix tables A.6, A.7, and A.8, alongside selected model diagnostics (see appendix table A.9 and figures A.1 to A.4), which allow for a deeper understanding of the underlying behavior of the chosen variables.

From the univariate GARCH results we can observe:

- A stronger significance, as well as lower magnitude of the interest rate coefficient β_{iI} (69% of the cases), with a mean value of -0.24, compared to -0.38 as estimated in the OLS regression.

- The world market risk factor is significant in 100% of the cases and does not show relevant variations in size compared to its estimation via OLS.
- The symmetric currency exposure betas β_{iC} are all positive and show an overall weaker impact (-0.56 as opposed to -0.70 estimated via OLS) but same percentage of significant cases as in the OLS process.
- The asymmetric exposure term β_{iC}^{d} shows on average a much weaker and negative impact (-0.001 vs. 0.23) on the country-industry excess returns but is significant in only 2 of the 16 regressions, both of which in the Financials sector. Therefore, we must again reject the hypothesis of a systematic asymmetric exposure to changes in exchange rates and we assume European stock returns to respond with the same intensity to appreciations and depreciations cycles.

Although the GARCH results do not show particularly large deviations from the OLS estimates, we can appreciate that OLS tends to overestimate the exposure to currency risk both under depreciation and appreciation regimes. This happens because the OLS approach does not decompose variable co-movements driven by volatility clustering from movements driven by random fluctuations. With the univariate GARCH analysis we clear the error terms from the predictable volatility due to volatility clustering, thereby effectively "turning down" the noise created by large shocks, whereas movements under calm periods are intensified. By doing this, this approach correctly focuses on unexpected FX movements, as opposed to movements driven by pure volatility dynamics inherent to financial data. Table A.9 (see appendix) reports the model diagnostics summarizing the estimated ARCH ($\alpha 1$) and GARCH ($\beta 1$) coefficients for each country–industry pair, together with their sum ($\alpha + \beta$) and an indicator for model convergence. Overall, we can observe a strong volatility persistence across all countries and industries, with values of $\alpha + \beta$ ranging from 0.92 to 0.99, which indicate very high persistence of volatility shocks and slow convergence to the long-run mean over time. The industry showing highest persistence is Consumer Discretionary, particularly in Italy and France, whereas the lowest levels of persistence are reported in Spain, specifically in the Telecommunications and Utilities sectors. When comparing the α and β coefficients, we observe that the volatility process is mostly driven by persistence of past variance (β) rather than by new shocks (α). All excess-return time-series estimations converged, indicating that the model is well-behaved and well-suited to the sample data and that the resulting volatility estimates are reliable. Additionally, these results confirm the presence of conditional heteroskedasticity in the error terms and suggest that the OLS residuals indeed suffer from volatility clustering, potentially spurious correlation estimates, as well as false significance, driven by mechanical co-movements of exchange rates with equity returns, especially during crisis periods. What the univariate GARCH framework still fails to capture, however, are the volatility dynamics across time series, namely across countries. In our European sample, where countries are highly interconnected and exposed to similar macroeconomic shocks, examining cross-country volatility co-movements is particularly important. The final step of our analysis consists in the multivariate GARCH model, which is specifically designed to address these interdependencies.

4.2 Multivariate GARCH

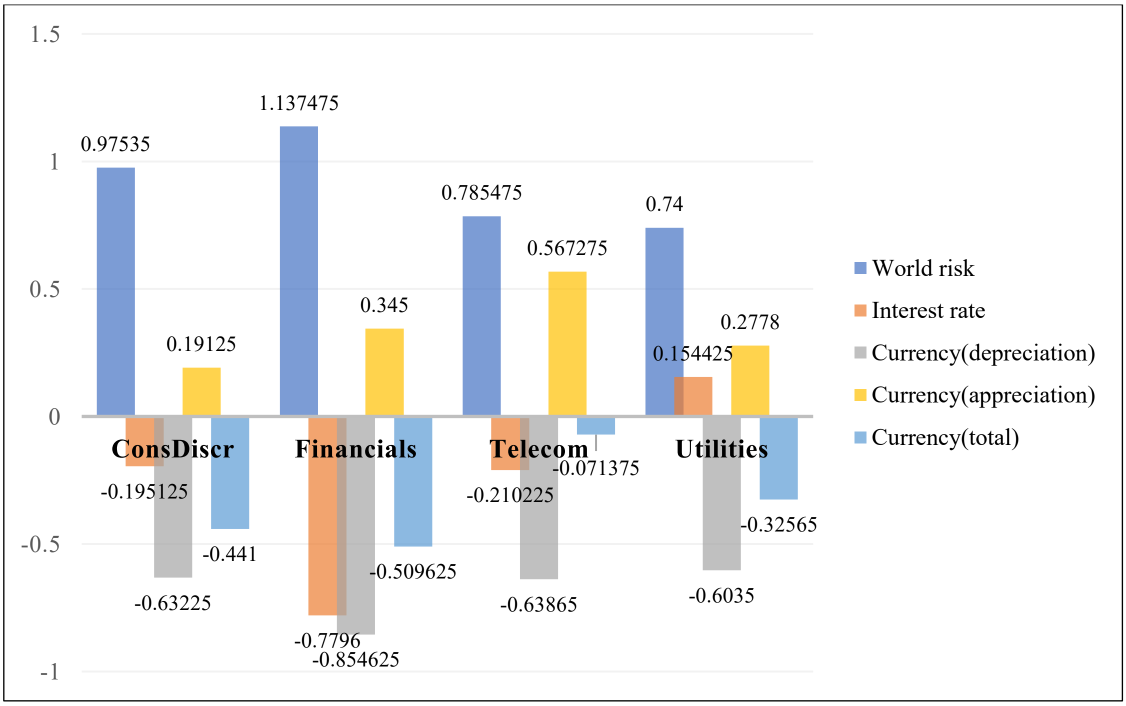
In our final and most relevant analysis step we estimate the exposure coefficients in the three-factor model using the multivariate DCC-GARCH framework. The results are reported in the appendix tables A.10, A.11, and A.12. Overall, we can observe that the world market risk factor is significant in all cases and exhibits an average coefficient of 0.90, indicating that, in line with previous estimations, all countries and industries are positively impacted by a strong performance of the world market, which is driven by general macroeconomic indicators. The interest rate risk factor shows an overall mean of –0.25, indicating that most industries' excess returns benefit from lower interest rate on government bonds. This is consistent with the results stemming from the univariate GARCH analysis, though with lower levels of statistical significance, indicating that the univariate GARCH estimates potentially contain residual "noise" caused by volatility movements across time series. The symmetric currency risk factor (β_{iC}) is significant across the entire sample of country–industry return series (100% significance), while approximately 25% of the sample displays significant asymmetric exposure to currency movements. These findings closely mirror those reported by Tai (2024) and reinforce the hypothesis that exchange rate exposure does indeed exert a significant influence on firms' ex-post stock returns, and that the low significance levels emerging in earlier studies likely stem from the use of weaker statistical methodologies. Looking at the results' breakdown by industry and country we can notice that the most striking differences arise across industry, whereas cross-country patterns display strong similarities in their exposure to world market risk, interest rate risk, and foreign exchange risk, with only a few notable exceptions. This particularly strong homogeneity most probably stems from the strong economic integration of European countries, as well as from their similar trade patterns with the United States. It is important to notice that the exposure estimates stemming from the MGARCH analysis measure the impact of a 1% change in exchange rates when holding the conditional volatility within time series, as well as the conditional correlations across times series constant. Thus, coefficients do not reflect the unconditional effect of currency movements on excess returns, rather they depict only the conditional marginal effects of such movements. Moreover, this methodology jointly estimates trade competitiveness effects, balance-sheet translation effects, and global risk dynamics. Therefore, isolating which specific exchange rate mechanism explains which portion of the variation in equity returns is, in this framework, not feasible. Before proceeding with the interpretation of the results, we conduct a diagnostic test on the univariate step of the DCC-GARCH, to assess whether the mean equation is well specified and the volatility dynamics are correctly captured within all country-industry time series. To this end, we perform a Ljung-Box test on both the standardized and squared standardized residuals and check whether they display leftover autocorrelation or ARCH effects, indicating that the resulting estimates are not reliable. The choice of this specific methodology is based on current literature, according to which the Box–Pierce/Ljung–Box portmanteau tests are the most widely used diagnostic checks to detect residual ARCH effects (Bauwens et al., 2006). We decide to perform this test individually on univariate time series, and not to implement the Hosking (1980) multivariate version of the Ljung-Box test statistics due to the high modelling and computational effort of the latter. It is important to acknowledge that, although the univariate Ljung-Box procedure is often used as a useful diagnostic step, it presents some technical inadequacies when testing both univariate and multivariate GARCH models (Silvennoinen and Teräsvirta, 2007); thus, its results should be interpreted with care (Bauwens et al., 2006).

The Ljung-Box test results (see appendix figures A.1 to A.4) are on average positive and show that both the mean equation and the volatility dynamics have been correctly captured. The only notable exception is France, where the mean equation test failed in 100% of the cases. This indicates that the standardized residuals in the mean equation of the four French industries are not white noise, rather they still contain serial autocorrelation and are as such not reliable. We check for potential data mismatches or abrupt spikes in the excess returns series of French industries, but we do not find signs of misbehaved industry-time series. To be able to interpret France's results reliably, we would need to remodel the mean equation, for instance by including ARMA dynamics capturing short-run persistence of excess returns, or by introducing additional regressors accounting for omitted drivers that might influence French equity returns. Since the immediate scope of this thesis is to check whether European industries show exposure to exchange rates overall, without inspecting the specific mechanisms producing this exposure, a re-estimation of French time series with a re-modeled mean equation is not included in this thesis.

In the following paragraphs we provide a breakdown of the MGARCH estimates, focusing on the most striking similarities and differences across industries, as well as across countries.

4.2.1 Results breakdown by industry

Figure 9: *DCC-GARCH mean exposures by industry*



The industry breakdown follows the FTSE Eurozone Sector Select Index Series, which only includes large and mid capitalization constituents in the Eurozone (FTSE Russell, 2023). Although we tried to identify the constituents of each sector index, we were only able to obtain a complete list for Italy. Because the selected index does not provide comprehensive constituent data for all sectors and countries, our analysis must remain at the industry level and cannot explore cross-country differences within the same industry in detail.

When focusing on cross-industry variations, Financials and Consumer Discretionary exhibit the strongest exposure to world market risk, whereas Telecommunications and Utilities are less exposed to fluctuations in global market returns. This difference is typically attributed to the regulated nature of the Telecommunications and Utilities sectors, as well as their predominantly domestic focus and relatively low integration into global markets. The utilities sector is strongly regulated both at the national and European levels, with limits on allowed revenues, monitored competition, and restricted market access. According to the Council of European Energy Regulators Report on regulatory frameworks for European energy networks, which provides an overview of the regulatory regimes applied across European countries, more than half of the surveyed countries apply incentive regulation through a revenue-cap mechanism, while the remaining countries rely on a combination of cap regulation and a guaranteed rate of return. Typically, the core parameter used to determine the allowed return on assets is the Regulatory Asset Base (RAB), calculated as the depreciated value of the assets required by the company to provide its services (Council of European Energy Regulators, 2025). The allowed return is then derived by applying the Weighted Average Cost of Capital to the RAB (Council of European Energy Regulators, 2025). These regulatory features reduce the overall sensitivity of stock returns to general market risk and help explain the lower β_{iw} coefficient observed in the Utilities sector. Similarly, Telecommunications display a lower exposure to world market risk primarily due to the more insulated nature of the sector. The telecom sector is also subject to European regulatory frameworks, including price-control obligations aimed at protecting consumers from monopolistic pricing, as well as rules governing infrastructure access and competition (European Parliament and Council of the European Union, 2018). Taken together, these factors partially shield telecom firms from large fluctuations in global markets, resulting in more stable stock returns that are less sensitive to global macroeconomic conditions.

Interest rate risk (β_{iI}) displays a negative impact on excess returns for all industries except within the Utilities sector. The inverse relationship between bond and stock prices is consistently observed across both OLS and univariate GARCH estimations and potentially reflects investors' tendency to reallocate from riskier assets toward safer securities when bond prices increase, thereby exerting downward pressure on equity returns. This flight-to-quality phenomenon typically arises during periods of market stress and occurs at the same time across multiple countries (Baur and Lucey, 2009). The opposite phenomenon is defined flight-form-quality and usually occurs when stock markets rise or bond markets fall (Baur and Lucey, 2009). It is important to specify that the relationship between stock and bond movements is time-varying and might flip sign during periods of greater stability. In general, it has been observed that the dispersion of stock-bond correlation is lower during crisis period, meaning that during such periods investors tend to behave similarly. The same cannot be said about periods of relative financial stability (Baur and Lucey, 2009). The sample period includes three major financial crises, the 2008 Global Financial Crisis, the 2010–2012 European sovereign debt crisis, and the 2019–2021 COVID-19 crisis; therefore, it is reasonable to assume that during this time frame repeated episodes of flight-to-quality occurred. Consequently, part of the predominantly negative correlation between bond and equity returns might be explained by these dynamics. In this framework, Utilities display an exceptional behavior, being the only industry exhibiting positive exposure to interest rate risk, which implies that their stock returns move in the same direction as government bond returns. A plausible explanation for this pattern is that utilities are widely regarded as bond-like equities due to their regulated revenues, stable dividend policies, and long asset duration. As a result, utility stock returns exhibit a stronger sensitivity to interest-rate and bond-yield movements than other equity sectors, often co-moving with government bond returns, particularly during periods of declining yields (Bodie et al., 2021). Changes in yields affect the discount rate applied to future cash flows, while expected cash flows remain largely unchanged thanks to government regulation, thereby increasing the net present value of future cash flows, leading to higher equity valuations. The formula below helps illustrate how changes in yields affect fixed-income securities and equities differently:

$$P_0 = \sum_{t=1}^{\infty} \frac{E\ (\ CF_t)}{(1+r)^t}$$

P_0 is the present value of a security, $E\ (CF_t)$ represents its expected future cash flow at time t, and r is the discount rate, which is typically composed of a risk-free rate, approximated by government bond yields, and an equity risk premium. An increase in bond prices corresponds to a decline in yields, which in turn lowers the discount rate applied to future cash flows. If the expected cash flow remains relatively stable, the present value of the security increases. Conversely, declining yields are associated with deteriorating growth expectations, therefore the resulting reduction in expected cash flows may offset the valuation gains generated by the lower discount rate. Since periods of rising bond prices often reflect negative expectations about future corporate earnings, investors tend to reallocate capital from riskier assets toward safer securities, leading to lower stock returns across most industries. Utilities, however, are characterized by stable and predictable revenue streams and are therefore perceived as less sensitive to unfavorable macroeconomic conditions, making them more attractive during periods of falling bond yields. Moreover, since utilities are typically highly leveraged, increases in bond prices and the associated decline in yields reduce both the discount rate and the cost of debt financing. This dynamic increases free cash flow and firm value, ultimately driving up utility stock prices.

Currency risk during periods of euro depreciation (β_{iC}) exerts a negative impact on stock returns across all industries. According to Parlapiano et al. (2017), the industry in which a company operates is one of the factors determining its level of exposure to currency risk. More specifically, empirical estimations consistently show a positive correlation between exchange risk sensitivity and firm-specific international operational variables, such as foreign assets, sales, and operating profits (Choi and Prasad, 1995). Other studies emphasize the role of competition in determining an industry's level of FX exposure: industries heavily engaged in global trade and facing greater competition, especially from global competitors, are often more exposed because their profits are highly sensitive to price changes induced by currency movements (Bartam et al., 2010). In our sample we observe that the financial sector displays the strongest negative exposure to euro depreciation, which can be attributed to the deep integration of European banks and financial institutions into USD-denominated markets. The European Banking Authority reports that reliance on USD funding within the European banking sector has increased in recent years, amplifying banks' exposure to exchange rate movements due to larger balance-sheet currency mismatches (Za and Spezzati, 2025). Overall, the European financial sector is particularly vulnerable to euro depreciation because key institutions, especially banks and firms in the broader private sector, depend heavily on borrowing in dominant foreign currencies, such as the U.S. dollar, while holding a significant share of their assets in local currency. This structural imbalance makes their financial performance highly sensitive to exchange rate fluctuations (Anaya Longaric, 2022). Previous empirical studies also found similar evidence, Parlapiano et al. (2017) for instance showed that the proportion of financial firms significantly exposed to currency risk is larger than non-financial firms, and that their average magnitude of their exposure is also greater.

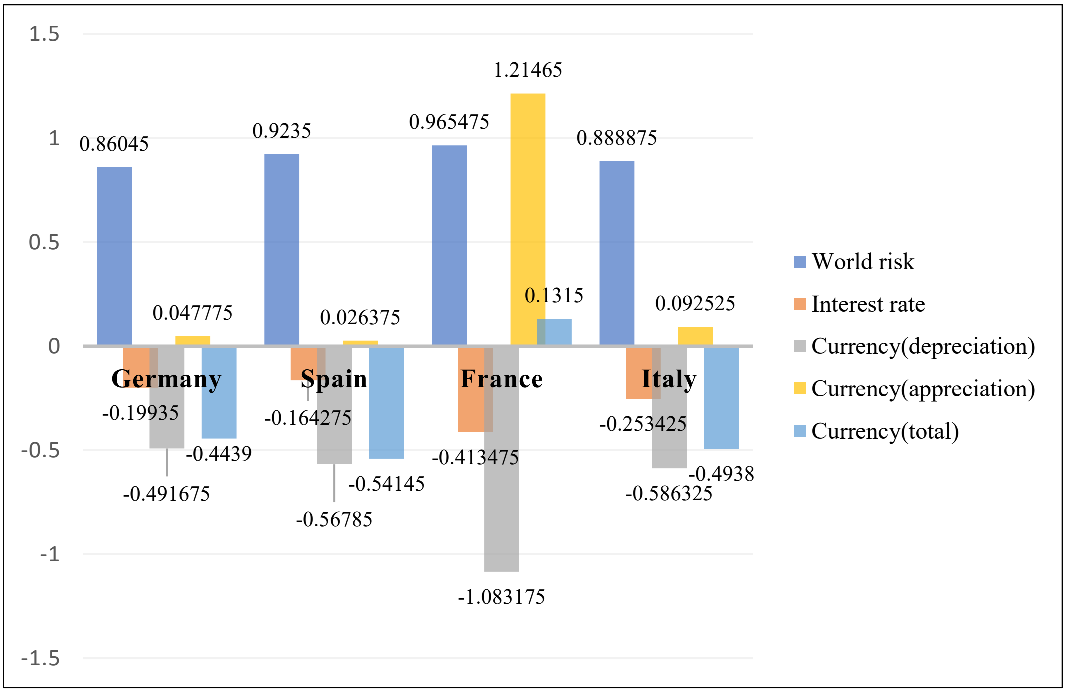
The second sample industry most strongly exposed to euro depreciation is the Utilities sector. This result does not align with the traditional argument predicting low exposure of utilities to currency risk due to their protection by government regulations and strong domestic focus (Adler and Dumas, 1984; Choi and Prasad, 1995; Muller and Verschoor, 2006). A plausible transmission channel of currency risk in the specific case of our sample countries operates through the input cost, energy sourcing and technology sourcing channel. European utility companies import machinery, reactors, industrial equipment, and chemicals, as well as more recently liquefied natural gas (LNG) from global markets, and increasingly from the United States, especially following the sanctions imposed on Russian energy supplies. Natural gas represents the second most important energy source in the European Union, accounting for almost 21% of total energy consumption in 2023 (Eurostat, 2025). According to recent data, in

2025 the United States supplied 58% of Europe's LNG imports and is expected to supply approximately 70% over the period 2026–2029, due the EU's plans to progressively ban Russian gas and LNG imports in the coming years (Buli & Kacher, 2025). This growing reliance on U.S. LNG increases the exposure of European utilities companies to euro depreciation vis-à-vis the U.S. dollar, as fuel procurement costs are largely denominated in USD. While crude oil imports from the United States constitute an important source of Europe's energy dependence on U.S. markets, they do not directly affect input costs and excess returns of utilities companies', since electricity and heat generation from oil has largely been phased out in Europe and currently accounts for less than 1% of total power and heat generation. The negative impact of euro depreciation on Utilities is reinforced by their largely unilateral exposure: European utilities firms, while importing fuel and raw materials from abroad, typically operate in domestic markets and do not export internationally; therefore, they do not benefit from improved export competitiveness when the euro depreciates. Moreover, according to previous empirical studies, utilities typically do not make large use of operational hedging techniques. In a study by Bradley and Moles (2002) it has been observed that 40% of utility companies reported using no hedging techniques at all (Bradley and Moles, 2002). Finally, Campa and Goldberg showed that energy and raw materials often exhibit the highest import price elasticities, meaning that, within this sector, import prices adjust almost completely and immediately whenever exchange rate fluctuates. This indicates that nearly all exchange rate fluctuations are eventually reflected in the cost of imported energy at the border, which in turn affects industry stock returns.

The Consumer Discretionary sector also exhibits negative exposure to euro depreciation, even though to a lower degree than Financials and Utilities. This sector comprises firms operating in industries such as automotive, apparel, luxury goods, household products, and leisure. Previous empirical findings show mixed evidence regarding the magnitude and direction of currency exposure within this sector. According to previous research, before accounting for operational and financial hedges, the automotive industry exhibits a high level of predicted vulnerability to currency shifts, which is significantly reduced by the large-scale usage of financial and operational FX hedges (Bartam et al., 2010). Textiles, clothing and footwear industries in Europe were found to have high average absolute residual exposure coefficients (Bartam et al., 2010), whereas the German consumer staples sector displayed lower currency exposure compared to other industries under observation (Tai, 2024). We hypothesize that consumer discretionary companies operating in Germany, Italy, France, and Spain are exposed to foreign exchange movements because they typically rely on imported intermediate goods and components from the United States, operate complex global supply chains, and are deeply involved in international trade. Data from the Observatory of Economic Complexity indicate that, within the Consumer Discretionary sector, Italy, France, Spain, and Germany generally maintain a trade surplus with the United States, implying that export volumes exceed import ones. To better assess the implications of currency depreciation for this sector in the sample countries, we present a breakdown of average net export volumes by product category vis-à-vis the United States over the period 2001–2023 (see appendix figure A.5). The product categories correspond to the first-level chapters of the Harmonized System classification defined by the World Customs Organization (WCO). From the table reported in the appendix we observe that the four European countries in the sample are particularly strong exporters in several Consumer Discretionary product categories, including transportation equipment, works of art and antiques, instruments, footwear and headwear, textiles, and other miscellaneous products. The negative impact of a weaker euro on firms operating in this sector, despite their strong export orientation, can be explained by several factors. Firstly, many of these firms also import intermediate goods and components from the United States. As a result, higher input costs during periods of euro depreciation may offset the gains in export competitiveness. And secondly, companies in the Consumer Discretionary sector often incur dollar-denominated operating expenses, such as costs related to international logistics and shipping, marketing and advertising services, e-commerce platforms, and various support services, including software licenses and technology-related inputs. These additional cost channels further compress profit margins during episodes of euro depreciation, negatively affecting firm profitability and value. The Telecommunications sector exhibits the lowest exposure to euro depreciation. This finding is consistent with the argument that, although telecom firms face some exposure to the EUR/USD exchange rate through imported inputs, their predominant focus on domestic markets and their regulated operating environment shield equity returns from currency fluctuations.

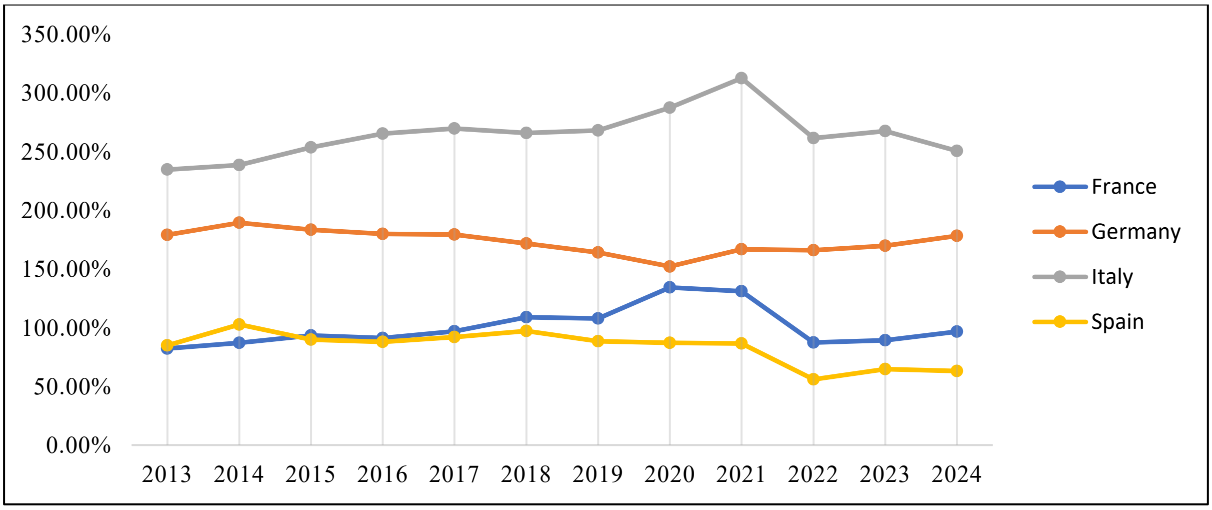
4.2.2 Results breakdown by country

Figure 10: *DCC-GARCH mean exposures by country*



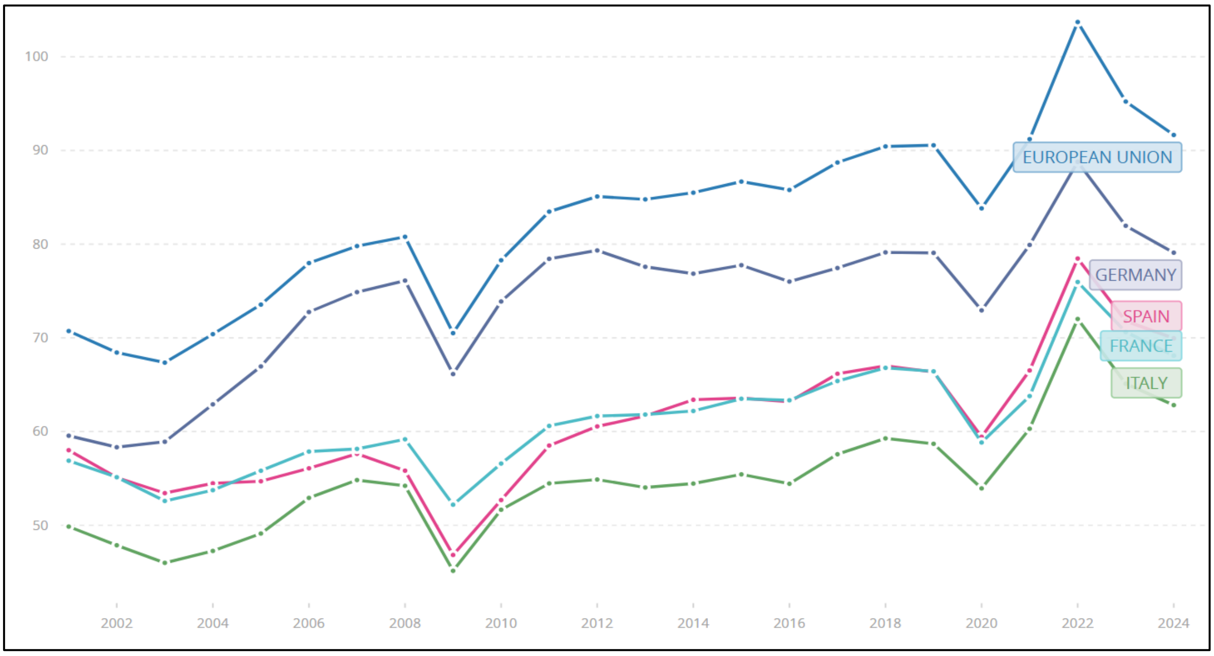
Before moving forward with the results breakdown by country, it is important to underscore that the choice of industries in our sample is too limited to be representative of each country's economy as a whole. We retrieved data relative to the trade volumes of the four sample countries with the United States (see figures 13 to 16) and we observe that the core industries driving each country's trade flows often do not overlap with the industries considered in our analysis. For instance, Germany's trade with the US is dominated by the machinery, transportation and chemicals sectors, which are not included in our empirical analysis. Italy's most traded goods with the US include machines, fashion and food products, only partially covered from the FTSE consumer discretionary industry index. Spain's core trade sectors are the agri-food, stone and glass, as well as other intermediate goods, which are better represented within the industry panel selected for the analysis. Finally, France's most traded goods are metals, chemicals and textiles, which again are not included in the industry data collected for the analysis. For this reason, the exposure estimated in our model cannot be generalized and interpreted as a country's exposure at its macroeconomic level. Since the four selected industries, with the exception of Consumer Discretionary, mainly include goods which are non-tradable or only partially tradable, our estimated exposure is expected to be lower than the average exposure at the country's level. This, despite being a limitation to the generalizability of our results, provides an interesting focus on the currency exposure of the four sample countries driven by energy imports, financial integration, and government regulation, rather than by pure trade competitiveness. From the cross-country comparison of the mean coefficients reported above, we immediately observe a high degree of homogeneity in the estimated exposures to world market and interest rate risk across the four sample countries. All countries exhibit strong exposure to global market movements, with coefficient values ranging from 0.86 to 0.96, indicating that equity returns in all cases benefit from positive performance in the global stock market. Interest rate coefficients are consistently negative and range from −0.41 to −0.16, implying that excess returns decline by between 0.16% and 0.41% for each 1% increase in government bond prices. Exposure to currency risk reveals strong similarities among Germany, Italy, and Spain, all of which display negative exposure under depreciation and no significant asymmetries in the exposure magnitude during periods of euro appreciation. The negative exposure to euro depreciation and positive exposure under appreciation in Germany and Italy might appear surprising, given the stronger export orientation of these two countries with respect to the United States. However, as previously explained in the context of the results breakdown by industry, the four European industries under observation rely heavily on the import of intermediate goods and raw materials from the United States for both production and consumption (Muller and Verschoor, 2006), which might partially offset the beneficial effect of a weaker euro on export competitiveness, for instance in the consumer discretionary sector. A notable exception to this pattern is represented by France, which exhibits a stronger exposure to euro depreciation, as well as a pronounced additional effect during periods of euro appreciation, resulting in an almost null exposure (+0.13) under appreciation regimes. Although similar results emerged in an empirical study conducted by Clark and Mefteh (2011), which analyzed a sample of 176 large, non-financial French firms and found that 61% of the significant exposures were asymmetric, it is important to remember that the mean equation test conducted on the univariate step of our MGARCH model failed in all estimations of French industries. This implies that the standardized residuals in the mean equation of French industries display some leftover autocorrelation and that the estimated betas, despite not being strictly invalid, are less reliable. We therefore reject the hypothesis that European countries are asymmetrically exposed to shocks in exchange rates; we assume instead that European equity markets benefit from domestic currency appreciation and suffer from depreciation in equal and opposite magnitudes (Koutmos and Martin, 2003). Previous studies identify several key determinants of a country's exposure to foreign exchange risk, the first one being a country's economic openness and trade intensity. As explained by Omar and Ahmad (2017), the estimated exposure to currency risk tends to be higher in smaller and internationally oriented economies, such as in emerging countries, which often display high volumes of imports and exports relative to their GDP. On the other hand, larger and more closed economies have been found to be systematically less impacted by exchange rate fluctuations (Omar and Ahmad, 2017). If we compare the currency risk estimates in figure 10 with the trade intensity of the sample countries reported in figure 12, we can notice that the trade intensity argument is not sufficient to explain the differences in the country's' exposure magnitude. For instance, Germany displays the highest trade intensity, but a lower currency risk exposure than in Italy and Spain, where international trade makes out a smaller percentage of the country's GDP. Similarly, France exhibits a level of exposure to euro depreciation that is approximately double that of Germany, even though France's trade intensity is on average 10 to 15% lower than in Germany. To be able to reliably identify the main drivers explaining the difference level of currency exposure across the four sample countries, we should conduct a comparative analysis of each sample industry's characteristics across the four selected countries. Since an analysis of this type goes beyond the immediate scope of this thesis, we will here limit ourselves to observing that, despite the relatively low trade intensity of the four sample industries, all four countries under observation display some residual exposure to foreign exchange risk. This aligns with previous studies arguing that even firms without direct involvement in international markets are exposed to currency risk. Adler and Dumas (1984) for instance found that U.S. companies without foreign operations, assets or liabilities are nonetheless impacted by currency fluctuations, since the demand for their products might still shift in response to changes in exchange rates. Parlapiano et al. (2017) also observed that European firms with a predominantly domestic focus are more exposed to currency risk than multinational corporations. This might be due to multinational firms' more pervasive use of operational and financial hedging. Dominguez and Tesar (2001) point out that companies operating in non-traded or only partially traded sectors must still compete for factors of production like labor and raw materials, which are often heavily affected by exchange rate fluctuations. To conclude our interpretation of the results across industries, we try to hypothesize whether including the core traded sectors in the four European countries under observation would substantially change the magnitude and direction of the estimated currency exposure betas. According to the trade data between the four sample countries and the United States provided by the Observatory of Economic Complexity, all countries are major exporters of machines and industrial products, and major importers of mineral products (see appendix figure A.5). These products are of fundamental importance for companies operating in the manufacturing, chemical, and transportation sector, which we did not include in our analysis, and therefore might bias our results. However, evidence from previous empirical studies focusing on the manufacturing sector highlighted a notable gap between high theoretical exposure of this sector, due to its strong integration into global markets and far-reaching supply chains, and the low risk measured empirically. For instance, Bartam et al. (2010) observed that most of the industrial firms analyzed in their sample display exposures close to zero, potentially due to their strong operational hedging, such as matching costs and revenues in the same currency (Bradley and Moles, 2002), as well as designing flexible supply chains, which allow them to switch between suppliers in different currency zones, as well as to share foreign exchange risk (Pellegrino et al., 2022). Bodnar et al. (1998) found that manufacturing is the sector with the highest and most pervasive use of foreign currency derivatives, with 95% of the firms actively engaging in financial hedging. Moreover, previous estimations of the currency exposure of European industrial firms, such as Muller and Verschoor (2006) found that most firms respond positively to euro appreciation and negatively to euro depreciations, which aligns with the results found in our empirical analysis. Finally, existing empirical studies do not provide evidence that the industrial sector displays a unique behavior in terms of its asymmetric exposure to currency risk. Several studies suggest that asymmetric responses are more present in the financial and consumer non-cyclical sectors (Koutmos and Martin, 2003), while the industrial sector is often found to be symmetrically exposed to currency movements (Koutmos and Knif, 2011). According to previous studies, the European chemical sector is one of the industries showing the strongest sensitivity to exchange rate risk. Similarly to our results, this sector is typically found to be positively impacted by a stronger euro and negatively impacted by periods of euro depreciation (Muller and Verschoor, 2006; Hutson and O'Driscoll, 2010; Koutmos and Martin, 2003). These findings align with the net-importer profile of firms operating in this industry, which rely heavily on imports of raw materials and especially mineral products from the United States (Muller and Verschoor, 2006). Previous studies do not provide significant evidence of asymmetric exposure of the chemical sector to exchange rate risk. Evidence on the currency exposure of the transportation sector closely resembles the exposure of the manufacturing and chemical industries, only with a particularly high vulnerability to currency fluctuations, due to this sector's high sensitivity to macroeconomic shocks (Hutson and O'Driscoll, 2010; Ito et al, 2016). Pellegrino et al. (2022) for instance, found that following the Covid-19 pandemic, oil imports from China decreased substantially, affecting shipping as well as exchange rates (Pellegrino et al., 2022), ultimately driving down the equity value of firms operating in the affected industries. Given all the reasons mentioned above, we do not expect our results to change substantially, having we included data from the industrial, chemical, and transportation sectors. The exposure is likely to remain symmetric, with equity markets responding positively to an appreciating euro and negatively when the euro depreciates, whereas the exposure magnitude might potentially increase, given these sectors' particularly high vulnerability to shocks in exchange rates. On the other hand, the currency exposure magnitude might remain unchanged or even decrease, if European industrial and chemical firms make a pervasive use of operational and financial hedging tools.

Figure 11*: Ratio of exports over imports with the United States per country*



Eurostat, 2025

Figure 12: *Trade volumes of sample countries (% of GDP)*



Country official statistics, National Statistical Organizations and/or Central Banks; National Accounts data files, Organization for Economic Co-operation and Development (OECD); Staff estimates, World Bank (WB); 2025

Figure 13: *Germany - US Net exports by product (in million dollars) over the years 2001-2023*

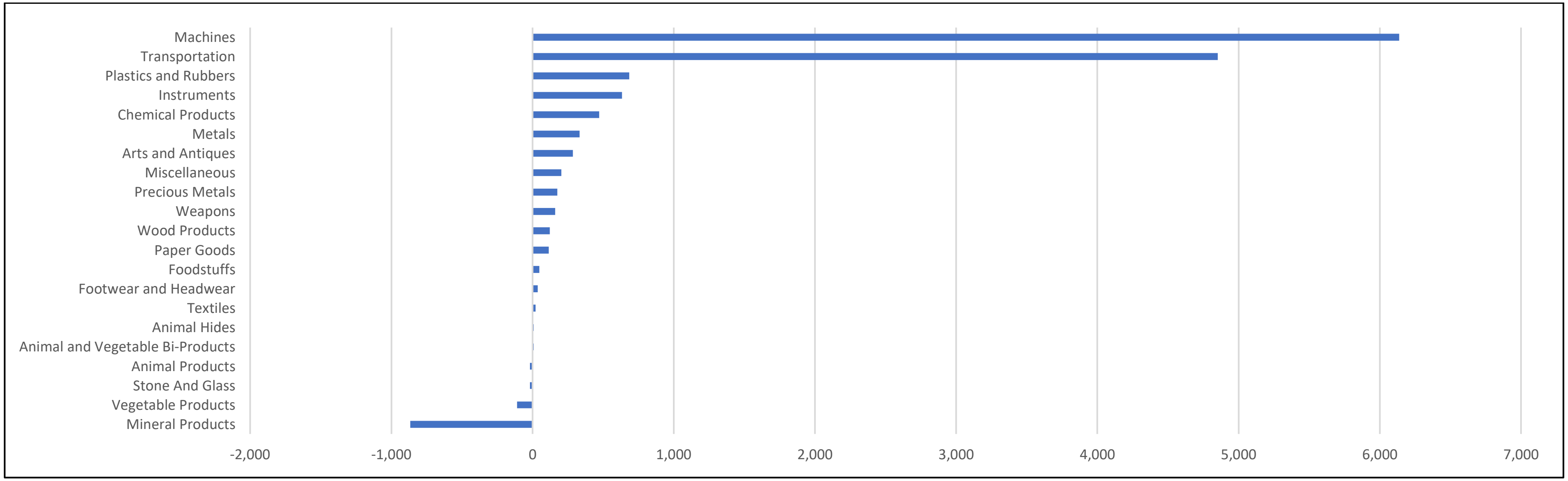


Figure 14: *France - US Net exports by product (in million dollars) over the years 2001-2023*

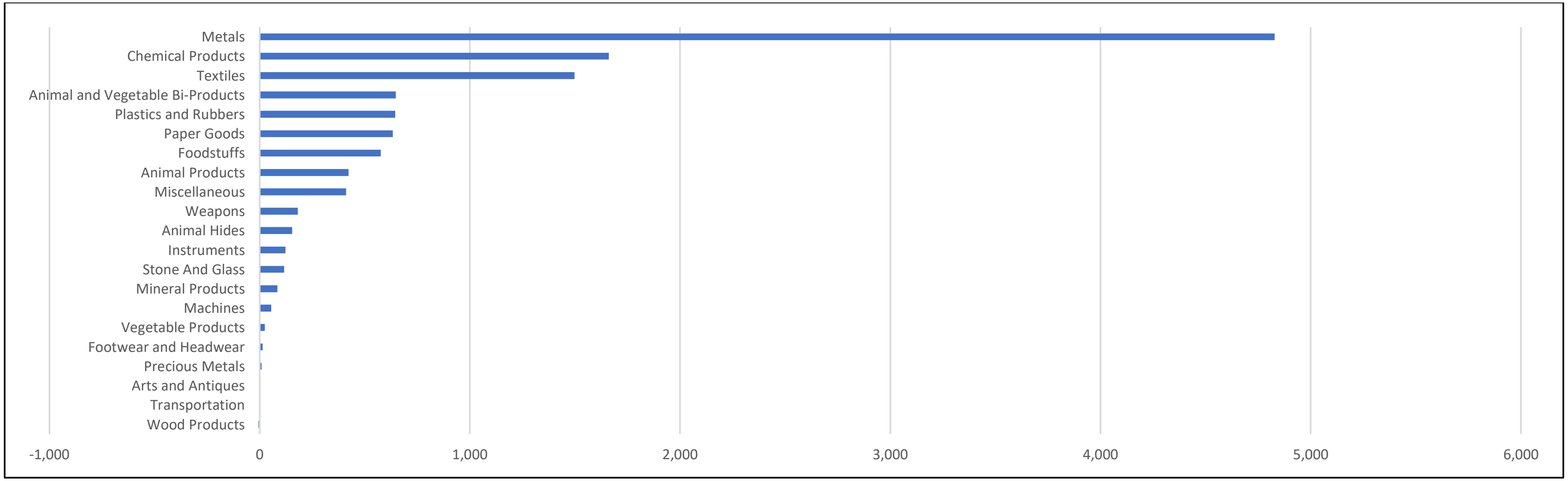


Figure 15: *Spain - US Net exports by product (in million dollars) over the years 2001-2023*

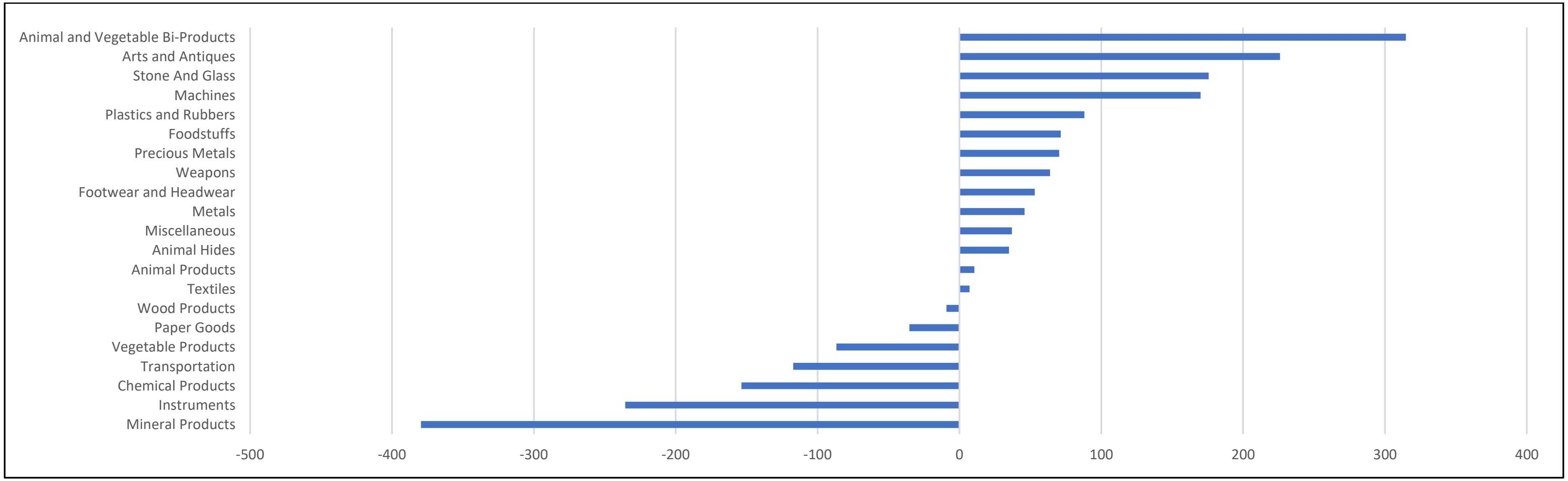
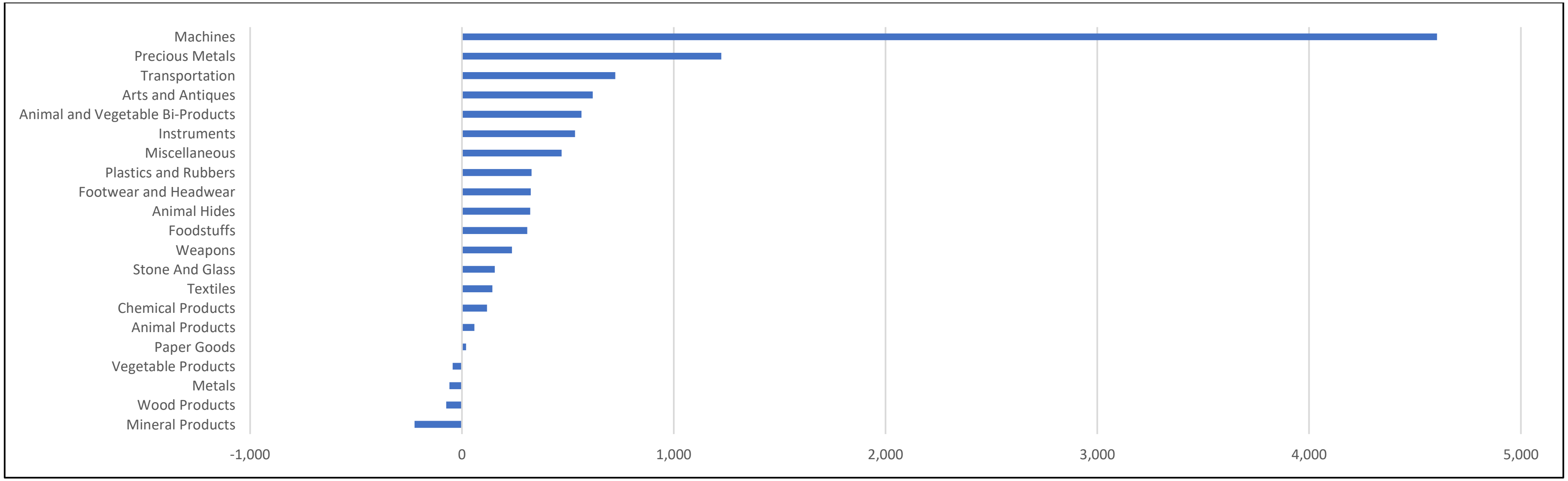


Figure 16: *Italy - US Net exports by product (in million dollars) over the years 2001-2023*



4.3 Results summary and discussion

In summary, the analysis suggests that European equity markets exhibit a predominantly symmetric exposure to period of Euro depreciation vis-à-vis the U.S. dollar. Equity markets in Germany, Italy, France, and Spain are negatively impacted by a depreciation of the euro, while they respond positively whenever the euro appreciates. While the exposure model implemented in this thesis adopts Euro depreciation as base regime, thus not allowing us to implicitly assume that stock returns display positive exposure to Euro appreciation periods. The rejection of the asymmetric exposure hypothesis, let us assume that European equity markets should react positively to Euro appreciations. Being the exposure symmetric, we conclude that there are no systematic changes in its magnitude between depreciation and appreciation cycles, meaning that stock excess returns move linearly with changes in exchange rates. These findings are consistent with the results obtained by Muller and Verschoor (2006), showing that phenomena of Euro depreciation have a negative impact on European stock returns, while periods of Euro appreciation boost returns in equity markets. Similar evidence has been found by Parlapiano, Alexeev, and Dungey (2017), who used an orthogonalized model to assess foreign exchange exposure for European firms using monthly data from 1999 to 2011. Again, the authors find that stock returns react positively to euro appreciation and explain this result by arguing that European firms are predominantly net importers and therefore benefit from a stronger euro, which lowers input costs and supports domestic consumption (Parlapiano et al., 2017).

Interestingly, the direction of exposure does not reverse when focusing on bilateral U.S.–Europe trade relations, where some European countries, such as Germany and Italy, are net exporters rather than importers. This suggests, on one side, that the traditional argument according to which weaker domestic currencies benefit export-led economies while stronger currencies favor import-led ones is insufficient to fully explain the impact of exchange rate movements on country–industry excess stock returns. Additional factors must be considered, including the high sensitivity of European supply chains to import costs, particularly for raw materials and intermediate goods sourced from the United States, which can partially offset the export competitiveness gains associated with a weaker euro. On the other side, these results expose one key limitation of the implemented methodology, namely that our three-factor exposure model does not explicitly disentangle foreign exchange impacts driven by pure trade effects from those reflecting broader movements in global market sentiment. Differently from the paper by Parlapiano (2017), we do not distinguish between expected and unexpected currency movements; thus, some of the residual currency exposure of stock returns is likely driven by "predictable" currency movements which respond to general macroeconomic conditions. According to Chari et al. (2023), the mechanism through which currency fluctuations influence equity returns is their impact on investor sentiment. In their paper, they design a Risk-on Risk-off (RORO) index, aimed at measuring the variation in global investor risk aversion. One of the main index components, besides equity market volatility, advanced economy credit risk, and liquidity are exchange rate dynamics. It has been observed that an increase in the U.S. dollar, or more generally any fluctuation in the U.S. dollar value, can act as a signal of a risk-off state, where investors tend to shift away from risky investments, such as stock markets, towards safe-heavens, driving down equity returns (Chari et al, 2023). In this sense, exchange rates are often a "symptom" of a broader shift in investor risk sentiment, which ultimately impacts returns in equity markets. Also important to underscore is that the chosen MGARCH methodology focuses on the estimation of the market FX exposure of stock returns, and not on the simple cash-flow FX exposure. According to the market logic, exchange rate instability in general negatively impacts stock market returns, regardless of the direction of exchange rate movements. This happens because exchange rate dynamics are inherently associated with a high degree of randomness, which introduces an additional source of systematic risk, for which investors demand higher premia. Therefore, large USD/EUR fluctuations, irrespective of their direction, tend to coincide with periods of increased global risk, tighter financial conditions or policy uncertainty, which drives drown firm valuation in equity markets across all industries and countries. Additionally, since firms involved in international markets actively hedge away currency risk, the asymmetric effect driven by impacts on cash-flow is minimal compared to the adverse effects of general exchange rate volatility. This interpretation is consistent with the literature documenting that stock returns respond more to exchange-rate risk and uncertainty than to mechanical translation effects (Bartram et al., 2010; Bekaert et al., 2023).

5. Limitations and conclusion

5.1 Limitations and future research

When interpreting the results of this study, we should acknowledge several limitations. First, the analysis relies on country–industry level return indices, which is standard in the exchange-rate exposure literature but may overlook significant firm-level differences. As noted by Dominguez and Tesar (2001), industry-level aggregation is often adopted, both because certain hypotheses are most naturally tested at the industry level, and because cross-country industry return data are more readily available. However, firms within the same industry may differ significantly in their operational structures, pricing behavior, and hedging strategies, implying that industry-wide exposure may not account for offsetting effects at the firm level. In particular, if firms within an industry are exposed to exchange-rate movements in opposite directions, aggregation may attenuate or even eliminate the exposure measured. This concern is further amplified by the use of value-weighted indices, such as the Datastream indices employed in this study, which place greater weight on large firms and may therefore reflect the exposure of dominant multinational firms rather than the industry as a whole. Second, while the rejection of the null hypothesis of zero exchange-rate exposure indicates that currency risk is economically relevant for equity returns, it does not allow a clear distinction between alternative underlying mechanisms. As emphasized by Dominguez and Tesar (2001), observed exposure may arise either because investors do not fully diversify away exchange-rate risk, or because firms do not fully hedge their foreign-currency exposures. In the absence of detailed data on investor portfolio holdings, currency invoicing, or firms' financial and operational hedging practices, the present analysis cannot disentangle these channels. Finally, the DCC-GARCH framework adopted in this thesis is a reduced-form approach that captures time-varying correlations and asymmetric exposure patterns but does not allow a causal interpretation of the estimated coefficients. Consequently, the proposed explanatory mechanisms, relative to industry characteristics, should be interpreted as economically consistent hypotheses rather than direct causal tests. Additional limitations in the empirical estimation of currency exposure lie in the endogeneity of corporate currency risk hedging, which makes the empirical testing of pre-hedging exposure very difficult (Bartram and Bodnar, 2007), as well as in the market independence bias. To overcome this issue Doukas et al., (2003) suggests orthogonalizing the foreign exchange market with the stock market, by estimating the residual market factor that is not explained by predetermined macro variables, including unexpected exchange rates. Furthermore, the use of short-term stock returns, such as daily or monthly data, might include a large portion of "noise", which makes it difficult to identify exchange rate exposure (Bartram and Bodnar, 2007). Studies show that the percentage of significant exposures increase rise as the time horizon of stock returns increases (Bodnar and Wong, 2003; Chow et al., 1997). Finally, this thesis' analysis is based on a small and homogeneous sample, focusing solely on the EUR-USD exchange rate in four developed European countries with similar economic structures and trade relationships with the United States. The significance of exchange exposure might decrease significantly when including a more diversified sample of countries and industries, covering also developing countries, where opposite effects might offset each other.

Potential ways to expand the analysis conducted in this thesis are firstly, the detailed inspection of firms' hedging practices, as well as how these practices affect the cross-industry and cross-country differences in exposure to currency risk. Secondly, following the methodology by Bartam et al. (2010), Tai (2024), Choi and Prasad (1995), and Parlapiano et al. (2017), the current sample should be integrated with data from the industrial and manufacturing sectors, since these firms are highly integrated into global supply chains and are among the most active users of risk management instruments. Furthermore, given the relevance of trade between the European Union and China, as well as neighboring Asian economies, replicating this empirical analysis considering the Euro-Chinese Renminbi currency pair could produce new and important evidence in the research on exchange rate exposures, as well as underlying the differences in FX exposure when considering a non-dominant currency.

5.2 Conclusion

In this thesis we contribute to the existing literature about foreign exchange risk exposure by investigating the impact of EUR-USD currency fluctuations on industry excess returns on a sample of four industries (Financials, Consumer Discretionary, Telecom, and Utilities) across four European countries (Germany, France, Italy, and Spain). The empirical analysis aims to provide further support to the argument that industry excess returns are exposed to currency risk and that the low significance found in previous empirical studies is mainly to be attributed to weak statistical methodologies, which failed to capture volatility dynamics inherent to financial data. After checking the existence of currency exposure on the selected sample, we try to identify what determines the exposure level of a specific country and industry, such as the characteristics of the industry sector, as well as differences in the trade relations between European countries and the Unites States. For this purpose, we replicate the methodology previously implemented by Tai (2024), consisting in the estimation of an asymmetric three-factor exposure model via Multivariate General Autoregressive Conditional Heteroskedasticity procedure. In the exposure model, the excess return of industry i in country j at time t $\left(r_{ij,t}\right)$ is described through a linear function of world market risk factor ($r_{w,t}$), interest rate risk factor ($r_{I,t}$), and currency risk factor ($r_{jc,t}$). Furthermore, in the model we decompose the exposure term into a base exposure β_{ijc} under Euro depreciation and an additional exposure β_{ijc}^{d} during periods of Euro appreciation. Before performing our main analysis step, we conducted two preliminary estimations on the same exposure model via OLS regression, as well as via univariate GARCH. The results stemming from these first two analysis steps are compared to the MGARCH estimations, to assess whether a more complex methodological approach such as MGARCH effectively achieves a higher level of significance and consequently more reliable results. The relevance of this research lies primarily in its European focus, which provides a deeper understanding of foreign exchange exposure in a strongly integrated economic area like the Euro monetary area. Moreover, our industry selection focuses on non-tradable or only partially traded goods, which allows to check for residual exposure to currency risk even in sectors with low trade intensity and limited integration into global markets. We find that OLS and univariate GARCH estimations already provide highly significant results, which are likely driven by the strong sample homogeneity and economic integration. OLS estimates tend to overestimate the exposure to currency risk since they do not disentangle volatility dynamics purely determined by volatility clustering from real random shocks. The univariate GARCH analysis confirms the existence of conditional heteroskedasticity in the excess return error terms and partially clears them from the volatility clustering "noise". All country-industry return time series showed very high persistence and slow convergence to their long-run mean. We finally re-estimate the coefficients and error terms via multivariate GARCH, accounting for interdependencies across the four European countries under observation by measuring the correlations across univariate time series. This procedure is performed with a Dynamic Conditional Correlation GARCH (DCC-GARCH) model, which represents a slightly simplified version of the diagonal MGARCH as proposed by Ding and Engle (1994) implemented by Tai (2024). Overall, the world market risk factor (β_{ijw})is significant in 100% of the cases and has a positive impact on excess returns, while interest rate risk factor (β_{ijI}) is significant in 56.25% of the estimations and on average displays an inverse relationship with excess returns. The currency risk factor under regimes of euro depreciation (β_{ijc}) is significant across the entire sample of country–industry return series (100% significance), while approximately 25% of the sample displays asymmetric exposure to currency movements (β_{ijc}^{d}). The most striking differences in the coefficient estimations arise across industry, whereas cross-country patterns display strong similarities in their exposure to world market risk, interest rate risk, and foreign exchange risk. The major exception emerging from the MGARCH results is the exposure to currency risk displayed by French industries, which, compared to the remaining sample countries, show a much stronger exposure to euro depreciation, as well as to euro appreciation. When performing a Ljung-Box diagnostic check on the univariate step of the DCC-GARCH estimations, we find that the mean equation in all four French industries is potentially misspecified, whereas volatility seems to be modeled accurately. Thus, we must assume that the exceptional behavior displayed by France might stem from the misspecified mean equation, rather than from a true deviation from the remaining three sample countries due to France's unique economic and trade features. At the industry level, we observed that industries more integrated into global markets and with far-reaching supply chains, such as Financials and Consumer Discretionary, tend to be more strongly exposed to all three risk factors, while industries like Telecom and Utilities, displaying a stronger domestic focus and being subject to government regulations, are partially shielded from unfavorable movements in any of the three risk factors. On the country level, we notice a strong homogeneity in the exposures to all risk factors, with the exception of France. All countries' excess returns respond positively to a strong global equity market, and negatively to higher returns on government bonds. Moreover, excess returns across the whole sample respond negatively to euro depreciation, while showing very low significance in the asymmetric exposure term during periods of euro appreciation. We therefore conclude that the four countries included in our sample are symmetrically exposed to changes in exchange rates, meaning that the exposure magnitude does not systematically change between appreciation and depreciations cycles, but that it simply flips sign. As mentioned in the limitations of this thesis, these results do not distinguish between foreign exchange impacts driven by pure trade effects from those reflecting broader movements in global market sentiment. For this reason, some of the residual currency exposure of stock returns is likely driven by "predictable" currency movements which respond to general macroeconomic conditions. The MGARCH procedure as performed in this thesis estimates the market exposure to currency risk, according to which exchange rate instability in general negatively impacts stock market returns, regardless of the direction of exchange rate movements. Therefore, large USD/EUR fluctuations, irrespective of their direction, tend to coincide with periods of increased global risk, tighter financial conditions or policy uncertainty, which decreases firm valuation in equity markets across all industries and countries. Further limitations of this thesis include the narrow sample selection, the industry-level data aggregation, the missing observations from core traded sectors, such as the manufacturing and chemical sector, as well as the endogeneity of corporate risk hedging and the market independence bias. Interesting challenges for future literature contributions would be to replicate this approach on a broader sample of European countries, including more sectors, multiple currencies, and potentially weaker economies to allow for a stronger sample diversification. Additionally, it would be interesting to conduct a comparative analysis by applying the MGARCH methodology by Tai (2024) and the orthogonalized model developed by Parlapiano et al. (2017) on the same sample, checking whether excess returns exhibit residual exposure to currency risk even when isolating unexpected from expected currency movements through orthogonalization.

6. References

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7. Appendix

Table A. 1:*Descriptive statistics of excess returns (all countries)*

Country	Industry	mean	sd	min	max	skew	kurt	n
DE	ConsDiscr	0.000004	0.035471	-0.244187	0.155696	-0.854426	5.361028	1,276
DE	Financials	0.000513	0.038394	-0.347463	0.228264	-0.918140	9.806253	1,276
DE	Telecom	0.000702	0.035849	-0.262372	0.236029	-0.679257	7.143225	1,276
DE	Utilities	0.000688	0.035689	-0.315622	0.147596	-1.079447	8.311631	1,276
ES	ConsDiscr	0.001428	0.034568	-0.231077	0.175821	-0.574700	5.131500	1,276
ES	Financials	0.000687	0.044601	-0.275062	0.261335	-0.396620	4.500154	1,276
ES	Telecom	-0.000154	0.035149	-0.235278	0.136720	-0.537213	3.920131	1,276
ES	Utilities	0.001633	0.029760	-0.293980	0.124339	-1.144302	11.108401	1,276
FR	ConsDiscr	-0.012950	0.037588	-0.293003	0.135434	-1.052056	5.367892	1,276
FR	Financials	-0.012012	0.047757	-0.293527	0.193558	-0.527224	3.919656	1,276
FR	Telecom	-0.012720	0.036661	-0.231967	0.151392	-0.334132	2.894217	1,276
FR	Utilities	-0.012725	0.041450	-0.417282	0.201245	-1.466697	12.117606	1,276
IT	ConsDiscr	-0.000654	0.038798	-0.215345	0.253499	-0.125774	4.111002	1,276
IT	Financials	0.000338	0.042484	-0.244442	0.226525	-0.860311	4.672442	1,276
IT	Telecom	-0.001047	0.044220	-0.349631	0.202896	-0.588058	5.565386	1,276
IT	Utilities	0.001240	0.030002	-0.312981	0.135384	-1.627336	14.063047	1,276

Table A. 2:*Summary statistics of risk factors*

Factor	**mean**	**sd**	**min**	**max**	**skew**	**kurt**	**n**
Currency risk	-0.0002	0.0125	-0.0496	0.0603	0.2193	4.4416	1,276
World market risk	0.0010	0.0235	-0.1979	0.1071	-0.9710	9.6340	1,276
Interest rate risk	0.0004	0.0085	-0.0365	0.0319	-0.1988	4.1219	1,276

Table A. 3:*Baseline OLS regression – all countries and industries*

Country	Industry	Intercept	β_{iw}	β_{iI}	β_{iC}	β_{iC}^{d}	$\beta_{iC} + \beta_{iC}^{d}$	R^2
DE	ConsDiscr	-0.001	1.093 ***	-0.436 ***	-0.661 ***	-0.011	-0.672	0.545
	Financials	-0.000	1.246***	-0.589***	-0.820***	0.099	-0.722	0.617
	Telecom	0.002	0.755***	-0.231*	-0.243	0.354	0.111	0.256
	Utilities	0.001	0.837***	0.038	-0.723***	0.217	-0.505	0.298
ES	ConsDiscr	-0.001	0.892***	-0.133	-0.460***	-0.205	-0.664	0.363
	Financials	0.002	1.197***	-1.175***	-1.179***	0.389	-0.790	0.509
	Telecom	-0.000	0.844***	-0.190	-0.580***	0.198	-0.381	0.319
	Utilities	0.003**	0.742***	0.004	-0.785***	0.449**	-0.336	0.345
FR	ConsDiscr	-0.014***	1.057***	-0.291**	-0.494***	0.110	-0.385	0.437
	Financials	-0.013***	1.404***	-0.998***	-0.978***	0.114	-0.863	0.542
	Telecom	-0.010***	0.718***	-0.276*	-0.438***	0.701**	0.263	0.230
	Utilities	-0.011***	0.970***	-0.186	-0.982***	0.603*	-0.379	0.312
IT	ConsDiscr	-0.002	0.913***	-0.374***	-0.444***	-0.054	-0.499	0.316
	Financials	0.001	1.159***	-1.076***	-1.109***	0.362	-0.746	0.514
	Telecom	-0.001	0.863***	-0.448***	-0.680***	0.277	-0.403	0.228
	Utilities	0.001	0.760***	0.160	-0.650***	0.212	-0.437	0.340

Total exposure = $\beta_{iC} + \beta_{iC}^{d}$. * $p \leq 0.1$, ** $p \leq 0.05$, *** $p \leq 0.01$

Table A. 4: *Number of significant exposures by industry (OLS regression)*

Industry	β_{iw}	β_{iI}	β_{iC} or β_{iC}^{d}	β_{iC}^{d}
ConsDiscr	4	3	4	0
Financials	4	4	4	0
Telecom	4	1	3	1
Utilities	4	0	4	1
Total	16	8	15	2
Total (%)	*100%*	*50%*	*93.75%*	*12.5%*

Significance at 5% level.

Table A. 5: *Mean exposures by industry (OLS regression)*

Industry	β_{iw}	β_{iI}	β_{iC}	β_{iC}^{d}	β_{iC} +β_{iC}^{d}
ConsDiscr	0.989	-0.309	-0.515	-0.040	-0.555
Financials	1.251	-0.960	-1.021	0.241	-0.78
Telecom	0.795	-0.286	-0.485	0.383	-0.102
Utilities	0.827	0.004	-0.785	0.370	-0.415
Overall mean	*0.966*	*-0.388*	*-0.702*	*0.239*	*-0.463*

Table A. 6: *Univariate GARCH mean equation estimation - all countries and industries*

Country	Industry	Intercept	β_{iw}	β_{iI}	β_{iC}	β_{iC}^{d}	$\beta_{iC} + \beta_{iC}^{d}$
DE	ConsDiscr	-0.000	1.038***	-0.294***	-0.605***	0.000	-0.605
	Financials	0.001	1.127***	-0.539***	-0.735***	-0.003**	-0.738
	Telecom	-0.001	0.688***	-0.149*	-0.113	0.001	-0.111
	Utilities	0.001	0.567***	0.174*	-0.513***	-0.001	-0.515
ES	ConsDiscr	0.000	0.937***	0.006	-0.480***	0.000	-0.479
	Financials	0.001	1.142***	-0.87***	-0.875***	-0.003	-0.878
	Telecom	-0.000	0.902***	-0.077	-0.622***	-0.001	-0.624
	Utilities	0.001	0.703***	0.28***	-0.413***	-8e-04	-0.414
FR	ConsDiscr	-0.004***	1.00***	-0.238***	-0.562***	-0.001	-0.563
	Financials	-0.009***	1.295***	-0.831***	-0.876***	-0.003	-0.879
	Telecom	-0.011***	0.73***	-0.288***	-0.272***	-0.002	-0.274
	Utilities	-0.006***	0.943***	-0.100	-0.668***	-0.003	-0.672
IT	ConsDiscr	-0.000	0.933***	-0.227***	-0.62***	-0.002	-0.625
	Financials	0.003***	1.018***	-0.727***	-0.786***	-0.005***	-0.792
	Telecom	-0.003*	0.859***	-0.328***	-0.468***	0.002	-0.465
	Utilities	0.000	0.736***	0.264***	-0.43***	0.0009	-0.434

Table A. 7:*Number of significant exposures by industry (univariate GARCH)*

Industry	β_{iw}	β_{iI}	β_{iC} or β_{iC}^{d}	β_{iC}^{d}
ConsDiscr	4	3	4	0
Financials	4	4	4	2
Telecom	4	3	3	0
Utilities	4	0	4	0
Total	16	11	15	2
Total (%)	*100%*	*68.75%*	*93.75%*	*12.5%*

Significance at 5% level.

Table A. 8:*Mean exposures by industry (univariate GARCH)*

Industry	β_{iw}	β_{iI}	β_{iC}	β_{iC}^{d}	$\beta_{iC}+\beta_{iC}^{d}$
ConsDiscr	0.980	-0.188	-0.568	-0.001	-0.569
Financials	1.146	-0.743	-0.819	-0.004	-0.822
Telecom	0.796	-0.211	-0.369	0.000	-0.369
Utilities	0.738	0.155	-0.508	-0.001	-0.509
Overall mean	*0.915*	*-0.247*	*-0.566*	*-0.001*	*-0.567*

Table A. 9: *Univariate GARCH(1,1) - Diagnostics*

Country	Industry	$\alpha 1$	$\beta 1$	$\alpha + \beta$	Converged
DE	ConsDiscr	0.0679	0.9017	0.9696	Yes
	Financials	0.1327	0.8296	0.9623	Yes
	Telecom	0.0542	0.9219	0.9761	Yes
	Utilities	0.0831	0.8870	0.9702	Yes
ES	ConsDiscr	0.0441	0.9452	0.9893	Yes
	Financials	0.0702	0.9240	0.9941	Yes
	Telecom	0.1125	0.8164	0.9288	Yes
	Utilities	0.1419	0.7895	0.9315	Yes
FR	ConsDiscr	0.1143	0.8803	0.9946	Yes
	Financials	0.1163	0.8592	0.9755	Yes
	Telecom	0.0562	0.9257	0.9819	Yes
	Utilities	0.0892	0.8744	0.9636	Yes
IT	ConsDiscr	0.0847	0.9124	0.9971	Yes
	Financials	0.1088	0.8856	0.9944	Yes
	Telecom	0.1394	0.8011	0.9406	Yes
	Utilities	0.0913	0.8751	0.9664	Yes

Figure A. 1:*Mean equation test on sample industries*

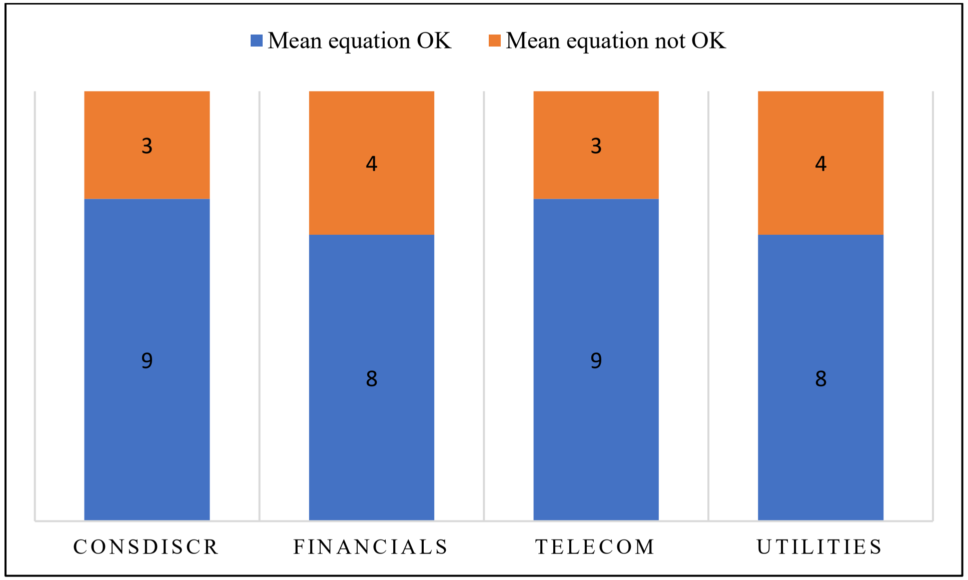


Figure A. 3: *Volatility test on sample industries*

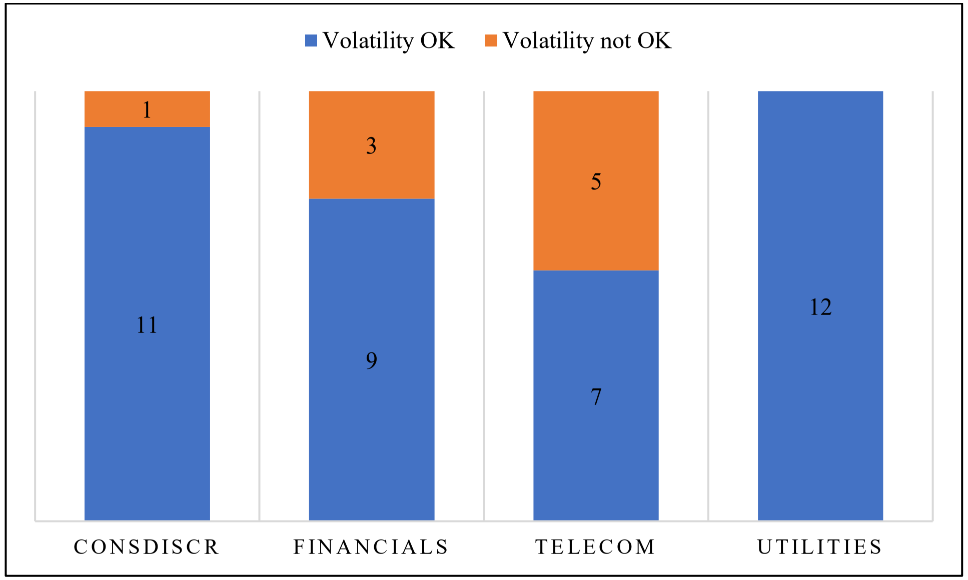


Figure A. 2: *Mean equation test on sample countries*

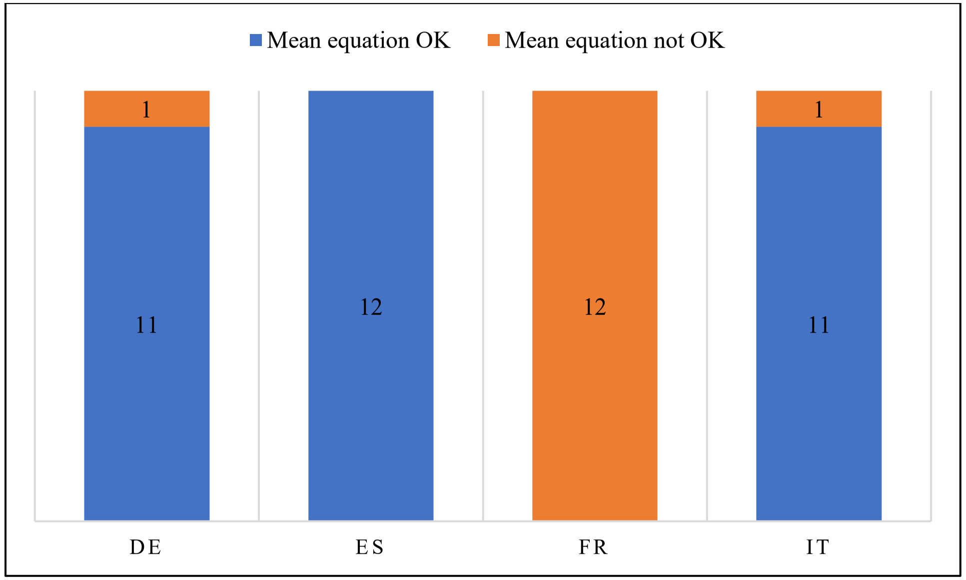


Figure A. 4: *Volatility test on sample countries*

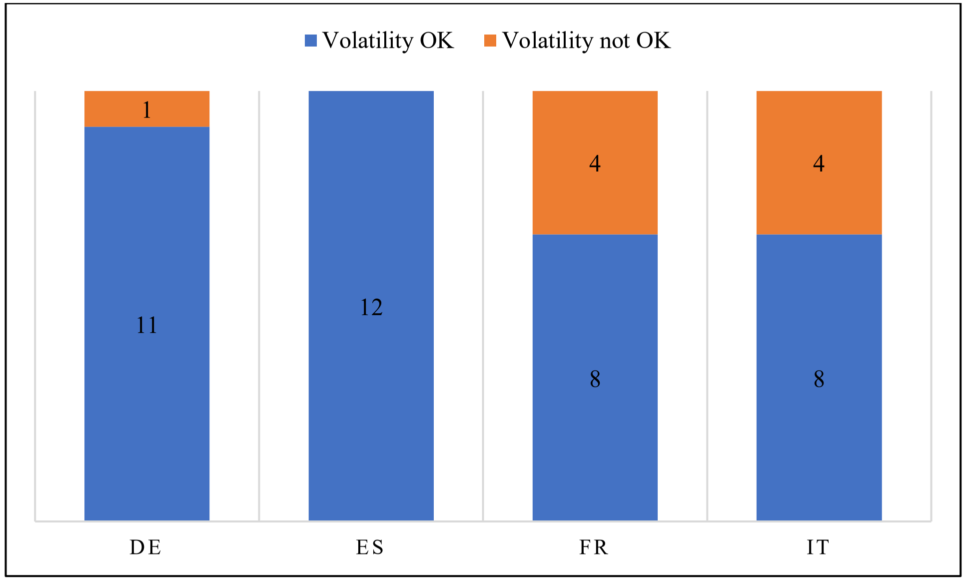


Table A. 10: *Multivariate DCC-t GARCH mean equation estimation - all countries and industries*

Country	Industry	β_{iw}	β_{iI}	β_{iC}	β_{iC}^{d}	$\beta_{iC} + \beta_{iC}^{d}$
DE	ConsDiscr	1.0366***	-0.2985***	-0.6084***	0.0024	-0.6060
	Financials	1.1312***	-0.5378***	-0.6344***	0.0190	-0.6154
	Telecom	0.6928***	-0.1395	-0.2689**	0.1893	-0.0796
	Utilities	0.5812***	0.1784.	-0.4550***	-0.0196	-0.4746
ES	ConsDiscr	0.9392***	0.0060	-0.4046***	-0.1769	-0.5815
	Financials	1.1456***	-0.8726***	-0.8007***	0.0579	-0.7428
	Telecom	0.8975***	-0.0819	-0.6688***	0.2279.	-0.4409
	Utilities	0.7117***	0.2914***	-0.3973***	-0.0034	-0.4006
FR	ConsDiscr	0.9941***	-0.2648***	-0.8493***	0.6982***	-0.1511
	Financials	1.2476***	-0.9750***	-1.4076***	1.3434***	-0.0642
	Telecom	0.6978***	-0.2877**	-0.9693***	1.6394***	0.6701
	Utilities	0.9224***	-0.1264	-1.1065***	1.1776***	0.0712
IT	ConsDiscr	0.9315***	-0.2232*	-0.6667***	0.2413*	-0.4254
	Financials	1.0255***	-0.7330***	-0.5758***	-0.0403	-0.6161
	Telecom	0.8538***	-0.3318*	-0.6476***	0.2125	-0.4351
	Utilities	0.7447***	0.2743**	-0.4552***	-0.0434	-0.4986

Table A. 11: *Number of significant exposures by industry (MGARCH)*

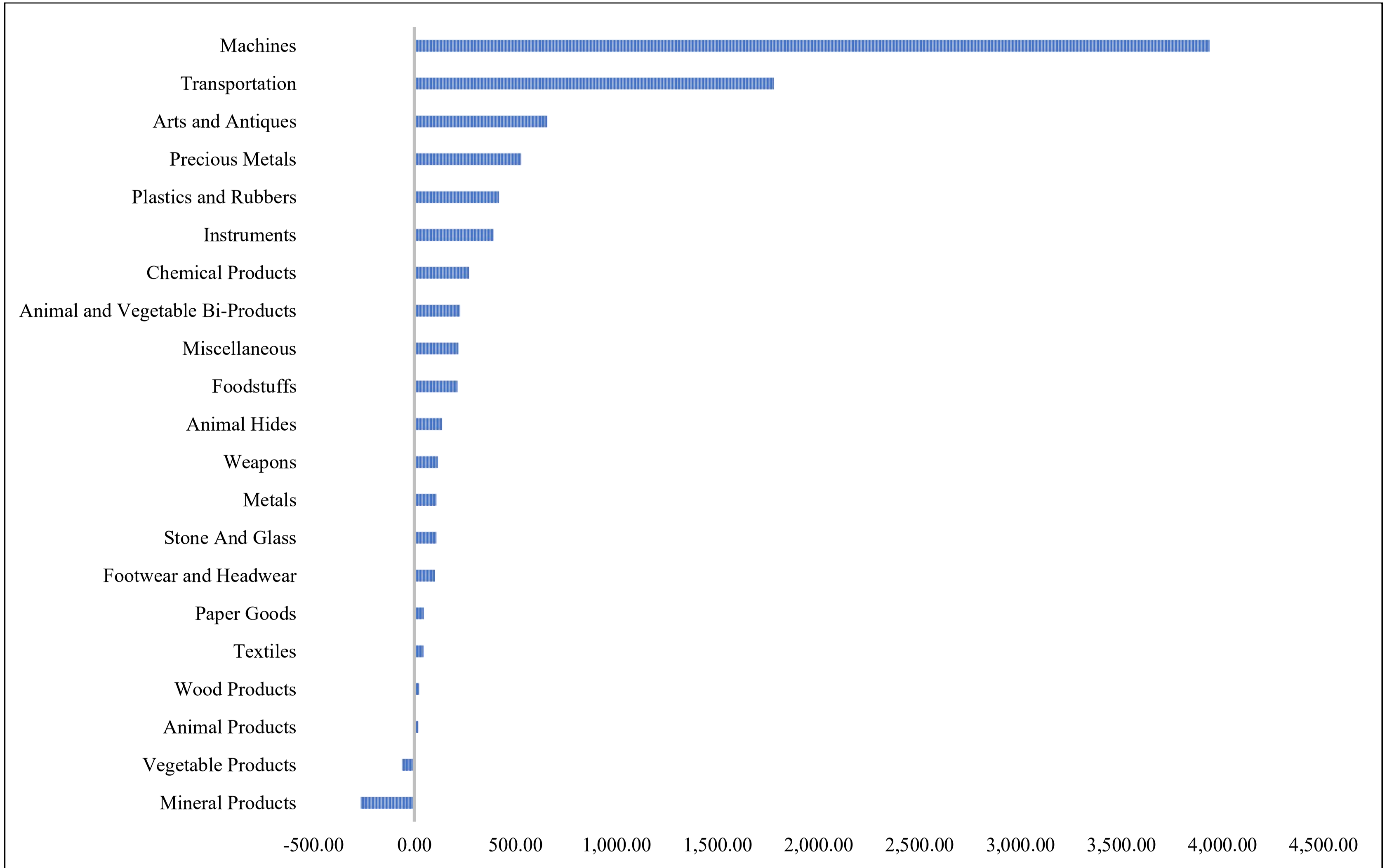
Industry	β_{iw}	β_{iI}	β_{iC} or β_{iC}^{d}	β_{iC}^{d}
ConsDiscr	4	2	4	1
Financials	4	4	4	1
Telecom	4	1	4	1
Utilities	4	2	4	1
Total	16	9	16	4
Total (%)	*100%*	*56.25%*	*100%*	*25%*

Significance at 5% level.

Table A. 12: *Mean exposures by industry (MGARCH)*

Industry	β_{iw}	β_{iI}	β_{iC}	β_{iC}^{d}	β_{iC} +β_{iC}^{d}
ConsDiscr	0.975	-0.195	-0.632	0.191	-0.441
Financials	1.137	-0.779	-0.854	0.345	-0.509
Telecom	0.785	-0.210	-0.638	0.567	-0.071
Utilities	0.74	0.154	-0.603	0.277	-0.325
Overall mean	*0.909*	*-0.257*	*-0.682*	*0.345*	*-0.336*

Figure A. 5: *Average of net exports across Germany, Italy, France, and Spain (over the period 2001-2023) in million dollars*



Observatory of Economic Complexity, 2025

Figure A. 6:*Germany's import and export volume with the US*

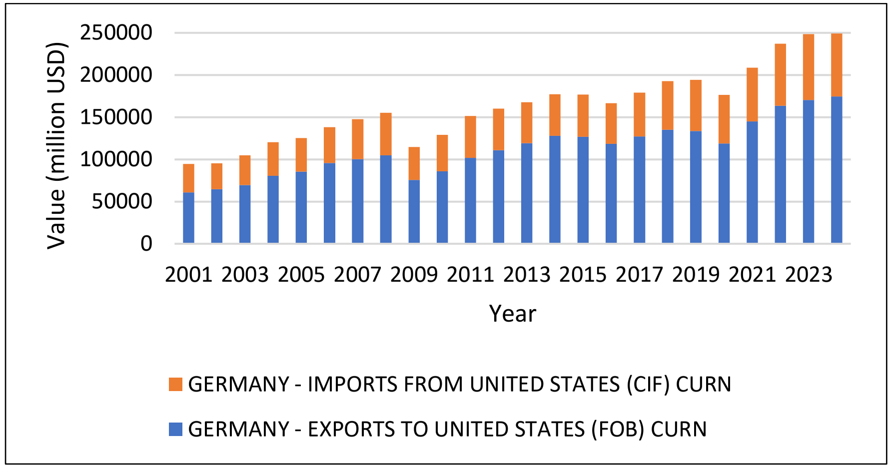


Figure A. 8:*France's import and export volume with the US*

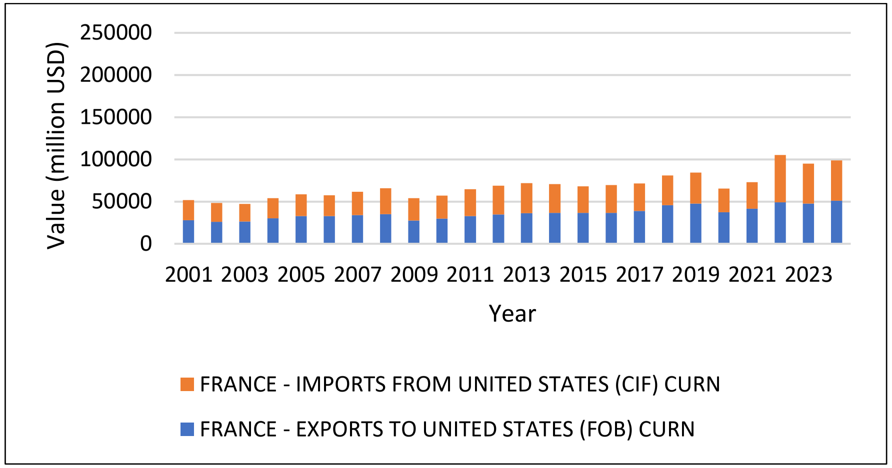


Figure A. 7:*Spain's import and export volume with the US*

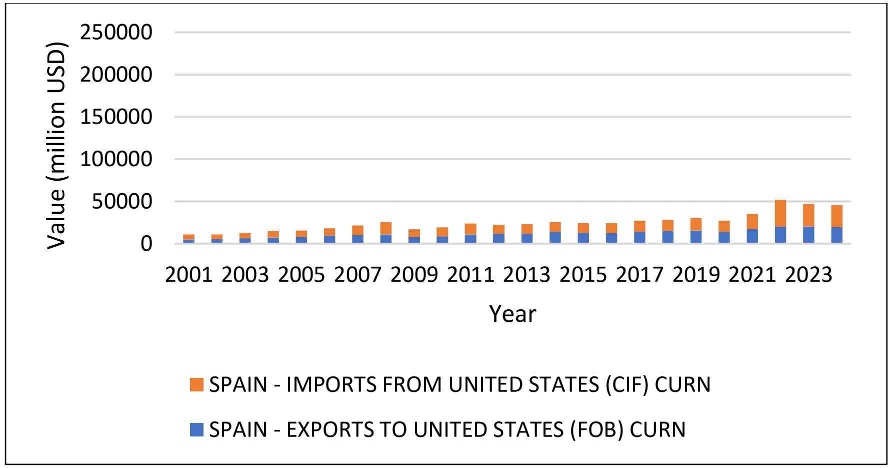
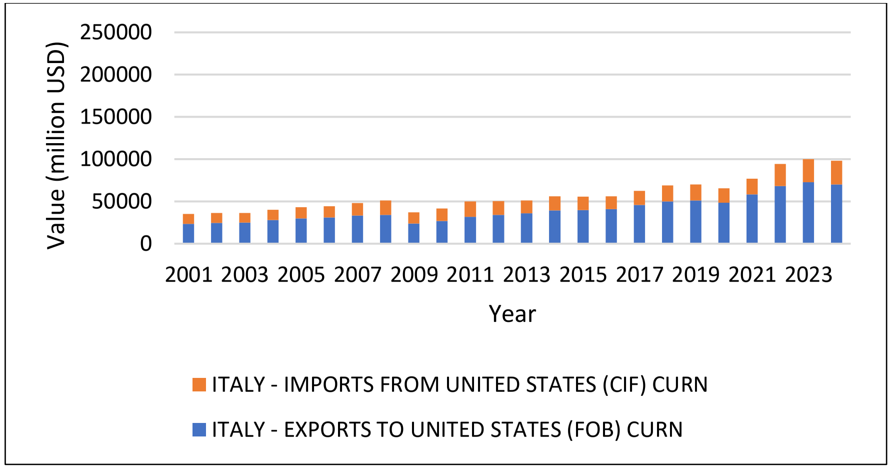


Figure A. 9:*Italy's import and export volume with the US*



Eurostat, 2025

Figure A. 10*:Germany - United States Balance of Trade*

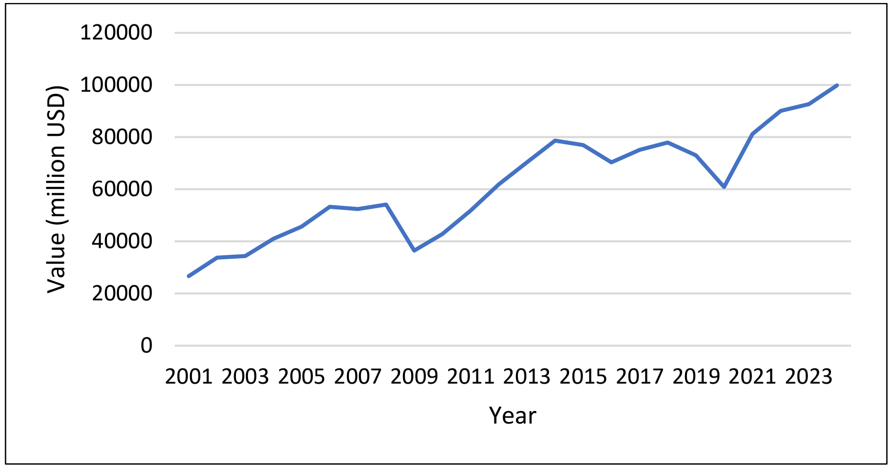


Figure A. 12*:France - United States Balance of Trade*

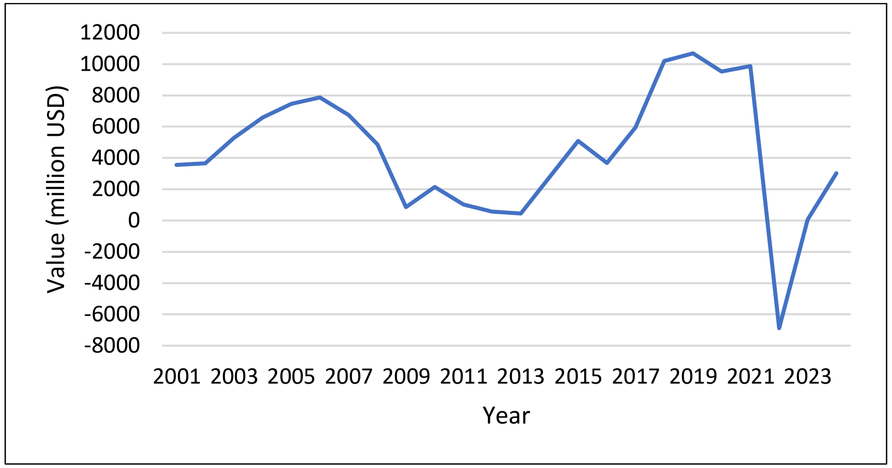


Figure A. 11*:Spain - United States Balance of Trade*

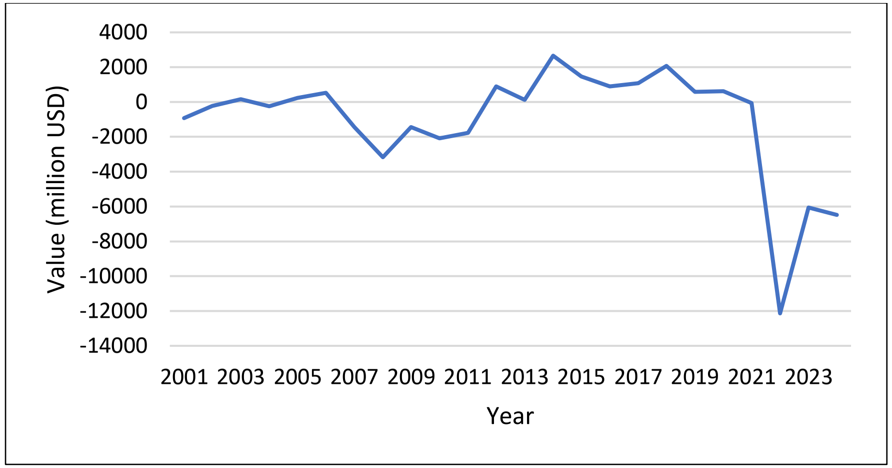
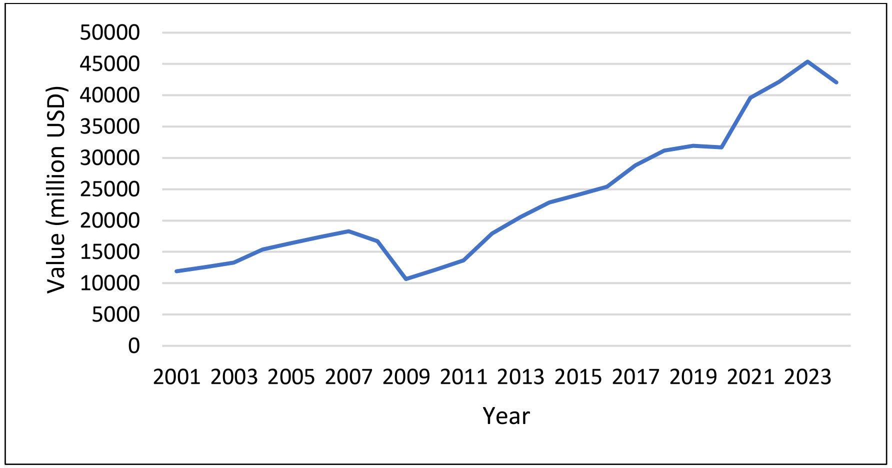


Figure A. 13*: Italy - United States Balance of Trade*



Eurostat, 2025