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Do Foreign Exchange Interventions Pay Off? An Empirical Assessment of the Prevented Damage for the Swiss Export Sector

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Abstract. This thesis conducts a cost-benefit analysis of the Swiss National Bank's foreign exchange interventions from 2009 to 2019, focusing on the Swiss export sector. To that end, the benefit of foreign exchange interventions in terms of the damage that would have occurred to the Swiss export sector in the absence of any foreign exchange interventions is calculated. The thesis is the first to conduct such an analysis for Switzerland and helps to put the costs of foreign exchange interventions in relation to their benefits. In a first step, the exchange rate elasticity of Swiss exports and the foreign exchange intervention elasticity of the real exchange rate are estimated. Subsequently, the prevented export sector damage is calculated using the two estimates. The calculation reveals that the costs of CHF 639.5 billion for foreign exchange interventions are CHF 77 billion higher than the benefits of CHF 562.5 billion. This difference seems justified in the light of the additional benefits that the foreign exchange interventions bring in terms of job preservation and creation and the prevention of structural changes in the Swiss economy.

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Contents

List of Abbreviations

CEPII-CHELEM	French Center for Research and Expertise on the World Economy
CHF	Swiss franc
CPI	Consumer Price Index
EA	Euro Area
ECB	European Central Bank
EU	European Union
EUR	Euro
FDI	Foreign Direct Investment
FX	Foreign Exchange
FXI	Foreign Exchange Intervention
GDP	Gross Domestic Product
HICP	Harmonized Index of Consumer Prices
IFS	International Financial Statistics
IMF	International Monetary Fund
KRW	South Korean Won
LC	Local Currency
LIBOR	London Interbank Offered Rate
M0	monetary base
M2	intermediate money
NBA	National Bank Act
NDA	Net Domestic Assets
NFA	Net Foreign Assets
OECD	Organisation for Economic Co-Operation and Development
OLS	Ordinary Least Squares
POLS	Pooled Ordinary Least Squares
PPP	Purchasing Power Parity
SARON	Swiss Average Rate Overnight
SCC	spatial correlation consistent
SDR	Special Drawing Rights
SECO	Swiss State Secretariat for Economic Affairs
SFCA	Swiss Federal Customs Administration

SNB	Swiss National Bank
UK	United Kingdom
US	United States
USD	US Dollar
VSTOXX	Euro STOXX 50 Volatility Index
2SLS	Two-Stage Least Squares
3M Libor	three-month Libor

List of Figures

List of Tables

1 Introduction

In 2020, Switzerland was labelled a currency manipulator by the United States (US) Treasury under the Trump administration, following several years on the currency manipulation watch-list. To be accused of currency manipulation by the US, a country must run a sizeable trade surplus with the US, have a current-account surplus that exceeds 3% of Gross Domestic Product (GDP), and spend more than 2% of GDP per year on the purchase of foreign assets. Besides reputational damage and threads to credibility, a country accused of currency manipulation by the US must fear punitive measures in the form of tariffs or restrictions on access to procurement (Politi & Szalay, 2020, pp. 1-2). Switzerland was removed from the currency manipulator list by the Biden administration. However, the questions remain why the purchase of foreign currency, so-called Foreign Exchange Interventions (FXIs), is essential to Switzerland, and what additional risks to those mentioned arise through the Swiss National Bank (SNB)'s FXIs.

Switzerland is a small open economy with few natural resources. Its heavy dependence on trade implies that the exchange rate is particularly important to the country (Moschella, 2015, p. 147). The Swiss franc is considered a safe-haven currency, which has resulted in massive inflows of capital after the global financial crisis in 2008 due to the increase in global risk aversion. The capital inflows put strong appreciation pressures on the Swiss franc and pose the risk of deflation (Thorbecke & Kato, 2018, p. 1182). Deflation constitutes a breach of the SNB's price stability mandate. Accordingly, the SNB has repeatedly affirmed that it intervenes in the Foreign Exchange (FX) market to address the deflationary risks arising from the capital inflows. Theoretically, the SNB can influence the inflation rate directly via short-term interest rates or indirectly by altering the exchange rate through foreign exchange market interventions (Hüfner, 2003, p. 79). However, having its interest rate at the zero lower bound, the SNB has de facto no other option than to use the unconventional exchange rate mechanism to steer Switzerland's inflation rate. This implies that the SNB must heavily conduct FXIs when appreciation pressures on the Swiss franc are strong and pose deflationary risks to the Swiss economy. The exchange rate and inflation/deflation are linked through the prices of imports. If the Swiss franc appreciates, prices of imports fall, which makes the local products less attractive and causes a decrease in local prices, eventually resulting in deflation. The opposite is true if the Swiss franc depreciates, i.e. costs of imports increase, causing inflation to rise.

While the SNB's FXIs are motivated by its mandate of price stabilization, the FXIs have the positive side effect of protecting the Swiss export sector. By preventing the Swiss franc from appreciating too strongly, the FXIs ensure that Swiss exports keep their price competitiveness in the international market, securing demand. Due to Switzerland's strong trade dependence, Swiss political discussions have always been marked by strong requests to depreciate the Swiss franc through FXIs from business associations and different parties across the political spectrum (Moschella, 2015, p. 147). Hence, while the SNB is an independent central bank, there is a political dimension to its FXIs. The currency manipulation accusations by the US demonstrate that the FXIs come at a particular cost, which must be evaluated against their potential benefits. A comprehensive cost-benefit analysis would consider the effects of the SNB's FXIs beyond the export and import sectors, which would exceed the scope of a master thesis. Therefore, the focus of this thesis lies on the costs and benefits of the SNB's FXIs for the Swiss export sector, which is justified by Switzerland's heavy export dependence. Specifically, this master thesis aims to evaluate the costs and benefits of the SNB's FXIs for the Swiss export sector by assessing the damage that would have occurred to the Swiss export sector in the absence of the SNB's FXIs. Knowing the costs that the Swiss export sector would have experienced in the absence of this unconventional monetary policy tool helps to quantify the benefits of the SNB's FXIs. This, in turn, allows assessing whether it is justified to take the direct and indirect risks that arise through intervening in the FX market to stabilize prices. In this respect, the findings of this thesis will help to put the magnitude of the SNB's FXIs into perspective and assess whether they seem justified from an export sector perspective. Given that Switzerland is not the only country with its monetary policy observed by the US, the findings of this thesis might be of broader interest. Vietnam and China have also been accused of currency manipulation, while Japan, Korea, Germany, Taiwan, Thailand, Italy, Singapore, Malaysia, and India have frequently appeared on the monitoring list (Weber & Shaikh, 2021, p. 433). While these countries might have different motives for conducting FXIs, the conclusions drawn about the costs and benefits of FXIs for the export sector might still be of interest to them.

The best approach to calculate the costs that would have occurred to the Swiss export sector in the absence of the SNB's FXIs would be to create a counterfactual showing the trajectory of Swiss exports based on an exchange rate that FXIs did not influence. The difference between the counterfactual and the actual volume of exports quantifies the costs that would have occurred to the Swiss export sector if the SNB had not intervened in the FX market. However, this approach involves considerable difficulties and is beyond the scope of a master thesis. Therefore, the potential costs are calculated using a three-step procedure. In a first step, a Pooled Ordinary Least Squares (POLS) estimation is used to estimate the exchange rate elasticity of Swiss exports. The aim is to quantify how many percent Swiss exports increase if the Swiss franc depreciates by 1%. In a second step, a Two-Stage Least Squares (2SLS) estimation is used to estimate the FXI elasticity of the real exchange rate. This estimation helps determine how many percent the real exchange rate decreases with a FXI of 1% of GDP. The 2SLS estimation is used to address the potential endogeneity of FXIs. Because intervention quickly reacts to exchange rate movements, exchange rates and intervention are likely determined simultaneously (Neely, 2005, p. 685). In the last step, the results of the two estimations are put together to calculate the overall Swiss export sector damage which the SNB prevented through its FXIs. Based on the percentage of GDP by which the SNB conducted FXIs, the results from the 2SLS estimation help determine how much these FXIs have depreciated the Swiss franc. The results from the POLS estimation can subsequently be used to calculate how much Swiss exports increased due to the FXIs. The period of interest spans from 2009 to 2019 as the SNB started its large-scale FXIs in 2009. The years 2020 and 2021 are not considered due to possible distortions spanning the novel Covid-19 pandemic.

This thesis contributes to the existing literature in two different ways. First, to the best of the author's knowledge, no publicly available cost-benefit analysis of the SNB's FXIs in general, and regarding Swiss exports in particular, has been conducted so far. This thesis closes this gap and delivers a basis for discussion of whether the risks that arise through the SNB's FXIs seem justified in the light of the benefits that the Swiss export sector and the Swiss economy get from using this unconventional monetary policy tool. Second, the estimations conducted as part of this thesis distinguish themselves from the previous literature because a novel proxy of FXI is used, which has been proven superior to previous proxies of FXI. The reason why the estimation relies on a proxy for FXI lies in the fact that the SNB does not publish data about its FXIs. Lastly, it is worth setting the scope of this thesis. There is a significant strand of literature that focuses on the question of whether FXIs influence the real exchange rate. It is not the aim of this thesis to contribute to this literature. The fact that the SNB relies heavily on FXI as a monetary policy tool suggests that its central bankers believe in its effectiveness, and this stance is not further questioned.

The remainder of this thesis is structured as follows. Chapter 2 introduces the SNB's unconventional monetary policy, the Swiss franc's safe-haven characteristics and the nature of the SNB's FXIs, followed by a discussion of potential risks that arise from FXIs. In Chapter 3, the exchange rate elasticity of Swiss exports is estimated using a POLS estimator. This is followed by the 2SLS estimation of the FXI elasticity of the real exchange rate in Chapter 4. In Chapter 5, the results from the POLS and 2SLS estimates are put together to calculate the costs that would have occurred to the Swiss export sector in the absence of the SNB's FXIs. The prevented costs for the Swiss export sector represent the primary benefit of the SNB's FXIs, but further benefits will be discussed. The amount by which the SNB intervened in the FX market during the period of interest represents the major costs of its FXIs, but further costs, presented as potential risks of FXIs in Chapter 2, will also be discussed. Finally, the benefits will be compared to the costs to draw an overall conclusion of the cost-benefit analysis for the Swiss export sector.

2 The Swiss National Bank's Unconventional Monetary Policy

This chapter aims to answer why FXIs are so important for the SNB. It introduces the SNB's monetary policy, focusing on the peculiarities of the Swiss franc and the necessity of the SNB to resort to unconventional monetary policy instruments, specifically to FXIs. In general, foreign exchange intervention denotes the practice of central banks buying and selling currency in the foreign exchange market to affect the domestic exchange rate (Neely, 2005, p. 685). In this thesis, the term FXI refers to the purchase of foreign currencies only, given that the SNB mainly was concerned about preventing the Swiss franc from appreciating too strongly during the period of interest. The current chapter briefly presents the SNB's monetary policy strategy and the safe-haven characteristics of the Swiss franc and subsequently describes the SNB's unconventional monetary policy from 2009 to 2019. This will give the reader a solid basis for understanding the remainder of the thesis. The second part of this chapter will examine whether the SNB's FXIs were sterilized or unsterilized, which is essential because it determines the extent to which FXIs influence the exchange rate. Lastly, the potential risks of FXI will be discussed to lay the foundation of the cost-benefit analysis conducted in Chapter 5.

2.1 The Swiss National Bank's Monetary Policy Strategy in Brief

The SNB's mandate is enshrined in the Swiss Constitution and the National Bank Act (NBA). The Swiss Constitution (art. 99) obliges the SNB, as an independent central bank, to conduct "a monetary policy that serves the overall interests of the country". The NBA (art. 5, para. 1) further specifies that the SNB "[...] shall ensure price stability. In doing so, it shall take due account of economic developments". The SNB's monetary policy is based on inflation targeting, whereby the SNB defines price stability as a rise in the Swiss consumer price index of less than 2% per annum. Deflation is considered a breach of the price stability objective (SNB, 2021, p. 9). Until 2019, the SNB has pursued the objective of price stability by using a target range for the three-month Libor (3M Libor) as the operating target and the conditional inflation forecast as an intermediate target. The SNB tried to keep the 3M Libor in the middle of this target range using the instrument of money market operations such as repo transactions. In June 2019, the 3M Libor target range was replaced by the Swiss Average Rate Overnight (SARON) as the SNB's policy rate to communicate the desired level of money market interest rates (Jordan, 2009a, p. 5; Baltensperger, Hildebrand, & Jordan, 2007, p. 19; Maechler & Moser, 2020, p. 4).

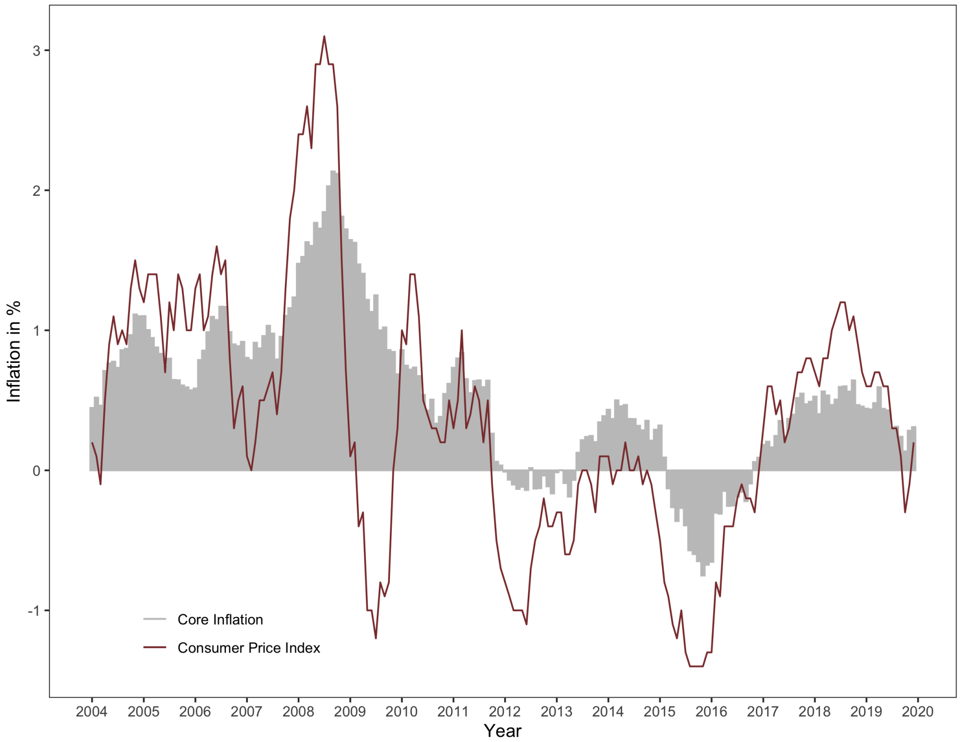
2.2 The Swiss Franc's Safe-Haven Characteristics

Switzerland is a small open economy, and as one of few currencies, the Swiss franc is resorted to as safe-haven in times of uncertainty. The flight to safety during international political or economic crises might be explained by Switzerland's political, institutional, social and fiscal stability and the low and stable inflation rate over many decades. The safe-haven function of the Swiss franc implies strong nominal and real appreciation pressures during times of global turmoil. In return for security, investors are prepared to hold investments in Swiss francs at lower interest rates than they would in other currencies. As a result, Switzerland's nominal and real interest rates have historically been very low, mostly below the corresponding European rates (Jordan, 2009a, pp. 5-6; Jordan, 2016, pp. 9-10). The small economy and safe-haven setting imply that the exchange rate significantly impacts inflation and the economy and therefore influences monetary policy decisions. Correspondingly, adjustments to the interest rate or interventions in the FX market impact the exchange rate. However, disregarding a few limited phases since the transition to flexible exchange rates in 1973, the Swiss franc exchange rate has never been an explicit monetary policy target. Before the global financial crisis, the SNB only deviated in very exceptional situations from the principle of not directly intervening in the FX market (Jordan, 2009a, pp. 5-6).

2.3 Unconventional Monetary Policy from 2009 to 2019

The collapse of the Lehmann Brothers in 2008 caused a sudden slump in the global demand for goods and services, which, together with the falling oil prices, provoked a sharp decline in inflation rates. As can be inferred from Figure 2.1, Switzerland's inflation measured by the consumer price index fell to a historically low -1%. Due to the Swiss franc's safe-haven role, the currency experienced an upward pressure that the SNB tried to counteract by lowering the target rate for the 3M Libor initially to 0.0%-1.0% and soon after to 0.0%-0.75%. Almost hitting what was regarded as the lower bound at that time, the SNB's room for manoeuvre using conventional monetary policy measures was de facto exhausted (Jordan, 2016, pp. 4-5). On March 12, 2009, the SNB announced that in addition to a further reduction of 25 basis points in the target range for the 3M Libor, it would resort to unconventional monetary policy measures to prevent a further appreciation of the Swiss franc and thus, combat the risk of deflation. The SNB started to purchase foreign currencies as well as Swiss franc bonds from private borrowers and entered more longer-term repo transactions with the banks (Hildebrand, 2011, pp. 6-7; Jordan, 2009a, p. 9; Jordan, 2009b, pp. 4-5; Jordan, 2010, pp. 3-4). The governor of the SNB, Thomas Jordan (2009a, p. 9), emphasized that "[. . .] the foreign exchange purchases should not be viewed solely in the light of their direct exchange rate effect. Rather, they are a complementary instrument for expanding monetary policy and increasing liquidity in a situation where the interest rate instrument can no longer be used because interest rates cannot be lowered below zero". Due to the Swiss franc bond market's relatively small size and the subordinate role of the Swiss capital market in the transmission of monetary policy, there was a limited possibility for quantitative easing via the purchase of bonds, an unconventional monetary policy instrument used for example in the US (Jordan, 2009a, p. 9).

Figure 2.1: Inflation of Switzerland from 2004 to 2019

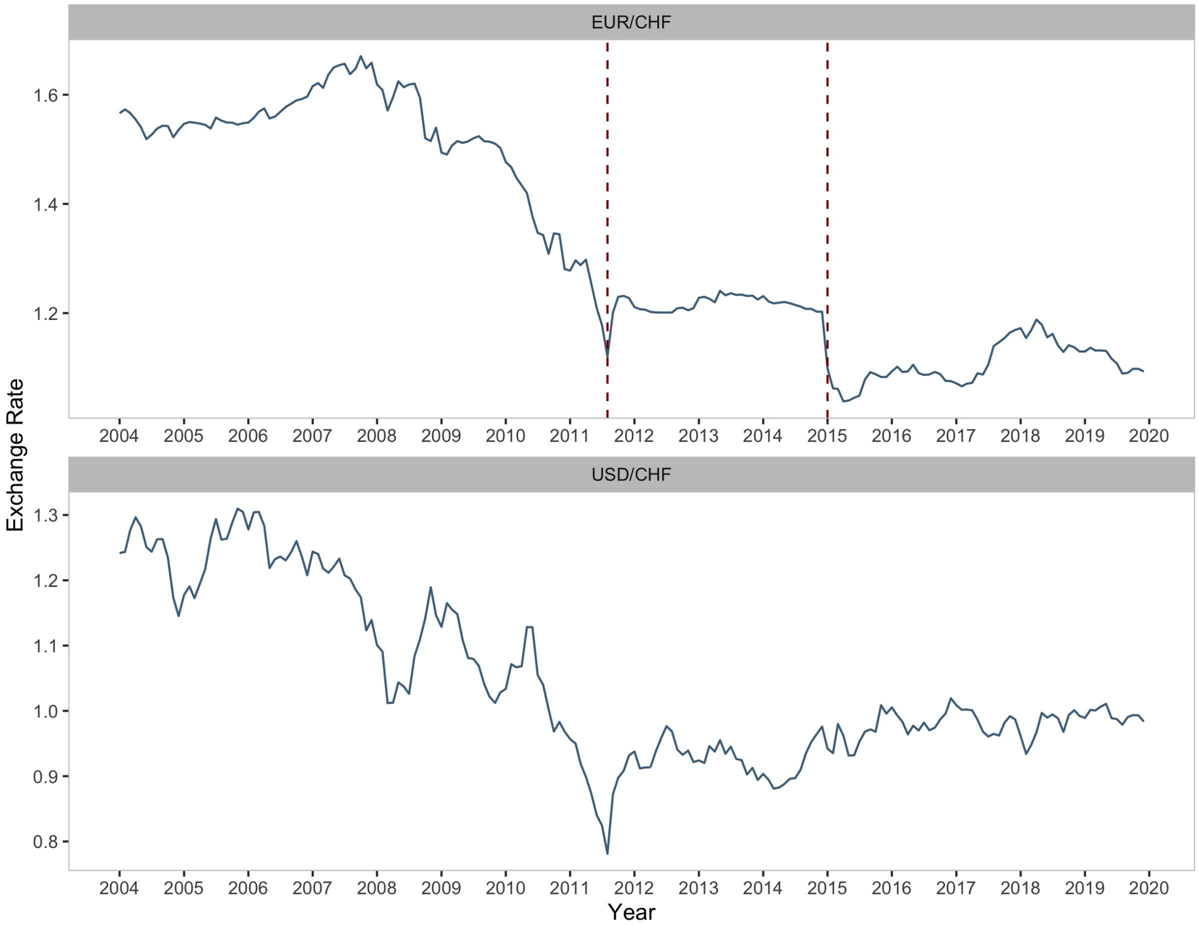


Source: Data from the Swiss National Bank, author's own depiction.

In spring 2010, the Swiss franc came under enormous appreciation pressure when the solvency of individual European states was questioned and caused a massive loss of confidence, resulting in severe tensions in the financial markets. The SNB reacted to the flight into safe Swiss franc investments by starting to purchase foreign currency on a large scale. By mid-2010, the SNB's balance sheet total amounted to Swiss franc (CHF) 300 billion, which marked an almost threefold increase compared to the beginning of the global financial crisis (Hildebrand, 2011, pp. 7-10). The European debt crisis considerably deteriorated the growth and inflation outlook for the euro area, causing a renewed appreciation of the Swiss franc against the euro. Figure 2.2 depicts the developments of the Euro (EUR)/CHF and the US Dollar (USD)/CHF exchange rates. In line with the data used for the estimation in Chapter 3, an increase in the exchange rate represents a depreciation of the Swiss franc. The figure indicates that while in 2007, the EUR cost CHF 1.65, it had fallen to almost parity by August 2011. The Swiss franc also appreciated strongly against the USD. In 2007, one USD bought CHF 1.25. In autumn 2011, the exchange rate temporarily fell to 75 centimes per dollar. The overvaluation of the Swiss franc against a broad range of currencies severely deteriorated Switzerland's economic and inflation outlook and posed a severe threat to the real economy. The SNB reacted with further liquidity expansions, which did not have a sustained effect (Jordan, 2016, pp. 5-6).

Against this backdrop, the SNB introduced a minimum exchange rate of CHF 1.20 per EUR as a temporary and further unconventional measure in September 2011 (cf. first vertical line in the upper part of Figure 2.2). The SNB was prepared to "enforce this minimum rate with the utmost determination" and signalled its willingness to "buy foreign currency in unlimited quantities" (SNB, 2011, p. 1). The minimum exchange rate was successfully enforced for more than three years due to the credibility of the SNB and the large-scale interventions in the foreign exchange market. The foreign exchange situation was stabilized, and the Swiss economy gained ground again. However, the FXIs left their mark on the SNB's balance sheet. Having stood at CHF 200 billion in August 2011, the SNB's foreign exchange holdings increased to CHF 490 billion by 2014, corresponding to roughly 75% of Switzerland's GDP (Danthine, 2015, p. 4). To put this into context, at the end of 2006, the SNB's balance sheet total amounted to CHF 112 billion (Studer, 2013, pp. 4-5).

Figure 2.2: EUR/CHF and USD/CHF Exchange Rate Development



Notes: Increase in the exchange rate represents a depreciation of the Swiss franc. The first red line represents the introduction of the minimum exchange rate EUR/CHF, the second red line represents its abolishment. Source: Data from the Swiss National Bank, author's own depiction.

In 2014, the Federal Reserve showed signs of an exit from a highly expansionary monetary policy, while the European Central Bank (ECB) gave indications of further monetary easing. Against this background, the USD began to appreciate while the EUR was strongly pressured downwards. These developments caused the CHF to depreciate against the USD and gradually approach the minimum exchange rate with the EUR. The ECB's monetary easing led to an almost complete disappearance of the interest rate differential between the euro area and Switzerland, forcing the SNB to massively intervene in the FX market to enforce the minimum exchange rate (Jordan, 2016, pp. 9-10).

The shift from an environment of pronounced CHF strength to an increasingly marked EUR weakness made the minimum exchange rate no longer sustainable. The increasing magnitude of interventions raised the danger of losing control over the balance sheet, comprising the SNB's ability to conduct monetary policy in the long term. The SNB assessed this threat by no means as proportional to the benefit that the continuation of the minimum exchange rate would have brought to the Swiss economy. Consequently, it decided to abandon the minimum exchange rate on January 15, 2015 (cf. second vertical line of the upper part in Figure 2.2). At the same time, it lowered its target range for the 3M Libor to the negative territory between -0.25% and -1.25% and reduced the interest rate on sight deposits to -0.75%. The lower interest rate compared to other countries should at least partially restore the interest rate differential to the euro area. The SNB saw the introduction of this unconventional monetary policy measure as the only way to reduce the attractiveness of the CHF and announced that it was willing to intervene in the FX market if necessary. In 2015, the SNB purchased foreign currencies in the amount of CHF 86 billion, causing the SNB's foreign exchange reserves to stand at CHF 560 billion by the end of the year (Jordan, 2015, pp. 2-3; Jordan, 2019, p. 4; Maechler, 2016, pp. 2-3). In the immediate aftermath of the currency floor removal, the CHF appreciated sharply against the EUR but weakened somewhat afterwards (Jordan, 2016, pp. 9-10).

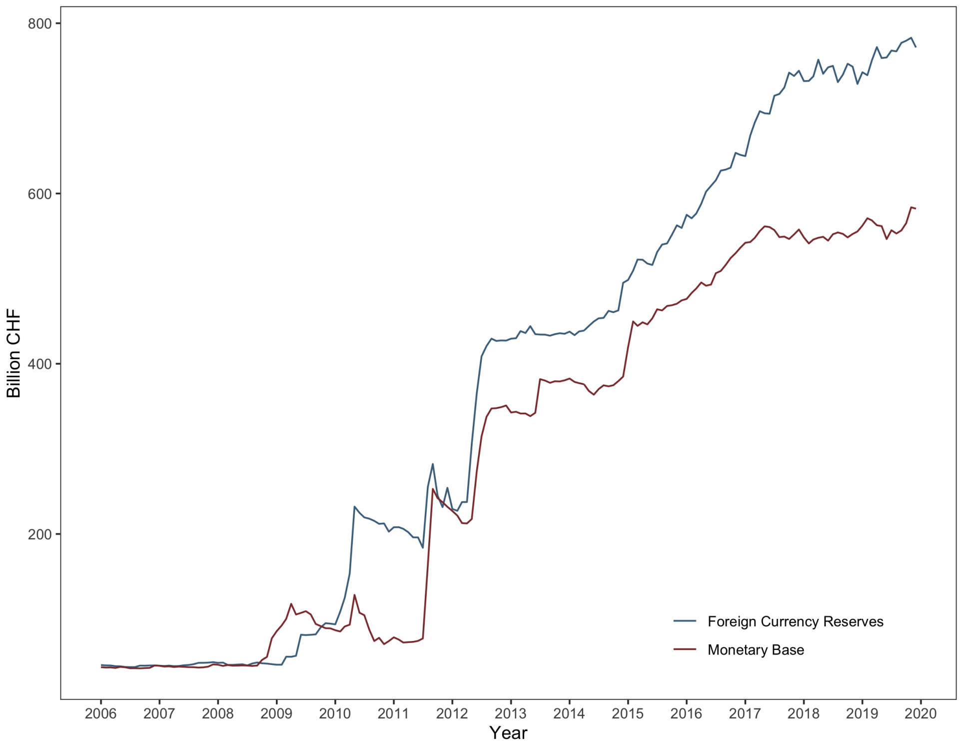
Since the minimum exchange rate discontinuation, the SNB has tried to mitigate the upward pressure on the CHF and ensure price stability over the medium term by conducting a monetary policy based on two pillars. Namely, the negative interest rates on sight deposits and the SNB's willingness to intervene in the FX market (Maechler, 2015, p. 2). The period after the discontinuation of the minimum exchange rate until the outbreak of Covid-19 was marked by a strong CHF, negative interest rates and low inflation. The uncertainty about the economic outlook caused by the outbreak of the coronavirus as well as major central bank's monetary easing that decreased foreign yields led to a flight to safe-haven currencies, exacerbating the long-standing problem of an upward pressured CHF (Jordan, 2020, pp. 5-6). The SNB reacted to these developments by stronger interventions in the FX market. In 2019, it purchased CHF 13.2 billion of foreign currencies, six times higher than in 2018 (SNB, 2020, p. 42). From the start of its FXI in 2009 until the end of 2019, the SNB purchased foreign currencies amounting to CHF 639.5 billion (SNB, 2009-2019)[1].

[1]Author's calculation based on the foreign currency purchases revealed in the SNB annual reports for 2009-2019.

2.4 Sterilization of Foreign Exchange Interventions

As mentioned at the beginning of the chapter, it is crucial to determine whether the SNB's FXIs were sterilized or not because this determines the magnitude of the FXIs' impact on the exchange rate. When selling Swiss francs in exchange for foreign currency, the SNB increases the number of Swiss francs in circulation, which raises its domestic money supply. The SNB can choose to either sterilize or not sterilize its FXI. Sterilizing means that immediately after purchasing foreign currency, the SNB sells domestic bonds to revert the effect on the domestic money supply. In contrast, foreign currency purchases are not offset by a sale of domestic bonds when conducting an unsterilized intervention, which increases the monetary base. The nature of FXI is important because of its effect on the exchange rate. Sterilized intervention does not influence prices and interest rates and has no direct impact on the exchange rate (Neely, 2005, pp. 687-688). The literature finds controversial results regarding a possible indirect effect of sterilized FXI on exchange rates. A discussion of the potential channels of influence is beyond the scope of this thesis. When it comes to non-sterilized FXI, there is a strong consensus that it can directly influence the exchange rate because the change in the monetary base directly affects interest rates and market expectations (Sarno & Taylor, 2001, pp. 841-842). Figure 2.3 shows the development of the SNB's foreign currency reserves and its monetary base. A closer look reveals that, from mid-2011 to the end of 2016, the monetary base tracked the SNB's foreign currency reserves quite closely, suggesting that the SNB did not sterilize most of its FXI.

Figure 2.3: The SNB's Foreign Currency Reserves and the Monetary Base



Source: Data from the Swiss National Bank, author's own depiction.

To analyze this in more detail, the following simple sterilization equation is estimated (Hüfner, 2003, p. 53):

$$\Delta NDA_t = \alpha_1 + \beta_1 \Delta NFA_t + \beta_2 \Delta NDA_{t-1} + \epsilon_t \tag{2.1}$$

where NDA denotes net domestic assets and NFA net foreign assets. Looking at the stylized SNB balance sheet in Table 2.1, it becomes clear that if the SNB does not sterilize its FXIs, the purchase of foreign currency increases Net Foreign Assets (NFA) and the monetary base (M0). In contrast, if the SNB sterilizes its FXI, it additionally decreases its Net Domestic Assetss (NDAs) through the sale of government bonds, leaving the monetary base unchanged (Sarno & Taylor, 2001, p. 842). Therefore, if the SNB completely sterilized its interventions, β_1 in Equation 2.1 should equal -1. A coefficient of -1 means that foreign reserve changes would be offset entirely to leave the monetary base unchanged (Hüfner, 2003, p. 53).

Table 2.1: Central Bank's Stylized Balance Sheet

Assets	Liabilities
Net foreign assets (NFA)	*Monetary base (M0)*
Gold	Total currency in circulation
Foreign	Reserve liabilities to commercial banks
Net domestic assets (NDA)	*Net worth (NW)*
Government securities	Spending surpluses
Loans on commercial banks	Net interests and capital gains from assets
Other	

Source: Sarno and Taylor (2001, p. 842)

An Ordinary Least Squares (OLS) estimation was used to estimate Equation 2.1 based on monthly data for the period 2009:01-2019:12. For details about the data construction, the reader is referred to Appendix 1. The time series were checked for unit roots using the Augmented Dickey-Fuller Test, and the first differences of all variables were taken to ensure stationarity. The lag of NDA is included to control for other influences on the dependent variable than sterilization (Hüfner, 2003, p. 53). The results of the estimation are displayed in Table 2.2.

The coefficient of NFA is negative but very close to zero, and the result is not statistically significant. Therefore, the null hypothesis of no sterilization cannot be rejected, indicating that the SNB did not sterilize most of its FXI from 2009 to 2019. This implies that the SNB's FXIs directly affected the real exchange rate, suggesting that the FXI elasticity of the real exchange rate, estimated in Chapter 4, is high in the Swiss case.

Table 2.2: Sterilization Estimation

	Net Domestic Assets
Intercept	-0.695
	(0.840)
NFA	-0.032
	(0.050)
NDA lagged	-0.167^{*}
	(0.085)
N	132
R^2	0.032
Adjusted R^2	0.017
Residual Std. Error	9.076 (df = 129)
F Statistic	2.110 (df = 2; 129)

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

2.5 Potential Risks of Foreign Exchange Interventions

This thesis focuses on the costs and benefits of the SNB's FXIs for the Swiss export sector. While the benefits can be understood as the damage which the SNB was able to prevent the Swiss export sector from through its FXIs, the costs refer to the monetary value of its FXIs and the potential risks that arise directly or indirectly through the conduct of FXIs. FXIs are accompanied by a massive expansion of the SNB's balance sheet, which entails several potential risks. First, according to the quantity theory of money, accumulating foreign reserves might result in inflationary pressures if the FXIs are not fully sterilized and result in an expansion of the money supply that exceeds the growth of money demand, jeopardizing the central bank's credibility (Moschella, 2015, p. 135). While the SNB conducted FXIs precisely to achieve inflation, inflationary pressures could get out of control if, for instance, the macroeconomic environment changes suddenly and unexpectedly. Steiner (2013, p. 112-113) showed that for a panel of 120 countries from 1970 to 2012, reserve changes were the primary source of change in the monetary base. This growth in central bank assets was responsible for inflation. In a later study, Steiner (2017, p. 126) showed that reserve growth unfolds its largest effect after three years, implying that the negative effects of reserve accumulation might not be sufficiently accounted for at the time of intervention. Hence, in the Swiss case, while FXIs were conducted to achieve inflation, FXIs might be risky because their lagged effect on inflation implies that the SNB has potentially not complete control over the unfolded magnitude of inflation. If inflation gets out of control, the SNB loses its credibility and has difficulty anchoring inflation expectations. This, in turn, makes it more difficult for the SNB to meet its inflation target in the future.

The second type of risk that can arise due to FXIs is a risk to the domestic financial stability. Increases in central bank foreign assets are most often accompanied by an expansion of the banking system's balance sheet. The change in the portfolio composition of commercial banks caused by reserve accumulation potentially leads to excessive credit expansion and investment, causing overheated credit and asset markets that a collapse of the banking system may follow. The threat to financial stability is more significant the less the FXIs are sterilized (Moschella, 2015, p. 135). Given the importance of the financial sector for the Swiss economy and the international reach of Swiss banks, Switzerland's domestic financial stability can potentially be threatened by macroeconomic shocks.

Third, a larger balance sheet, particularly a larger foreign currency position, implies that the SNB is more exposed to valuation effects. These effects lead to a more considerable fluctuation in the financial results and bear the risk that the SNB might suffer from valuation losses. The risk is more significant the less diversified the SNB's foreign currency position (Maechler, 2015, pp. 3-4). Usually, this kind of risk is referred to when talking about the direct risks of FXIs.

Lastly, there are opportunity costs associated with the accumulation of foreign reserves, given that they are primarily invested in low-yielding assets. In their study, Beck and Weber (2011, p. 416) found the level of diversification of central bank reserves to be low and move towards safe assets as the level of reserves increases. The SNB seems aware of the potential risks arising from the accumulation of foreign currency reserves due to its FXIs and has demonstrated some efforts to diversify its investments across various currencies and instruments. However, as the president of the SNB Council for the period 2012-2019 noted in this context, "the level of risk remains very high" (Studer, 2013, p. 4).

Chapter 5 will assess whether the four types of risks mentioned did materialize in Switzerland from 2009 to 2019. If so, the costs of their materialization will be added to the amount of FXIs conducted by the SNB during the period of interest to get the total costs. These can then be compared to the benefits, i.e. the prevented Swiss export sector damage.

3 Exchange Rate Elasticity of the Swiss Export Sector

The previous chapter shed light on why the SNB relied heavily on FXIs as a monetary policy instrument and laid the foundation for the cost-benefit analysis of the FXIs for the Swiss export sector. The current chapter contains the first step to calculate the prevented export sector damage, which will be used to quantify the benefits of the SNB's FXIs. To better understand the importance of the Swiss franc for the Swiss export sector, the chapter first sets out the development and characteristics of Swiss exports from 2009 to 2019. Subsequently, it summarises the empirical literature about the exchange rate elasticity of Swiss exports. In the last step, the exchange rate elasticity of Swiss exports is estimated for the period of interest using a pooled OLS estimation, and the validity of the results is discussed based on several robustness checks. Knowing the exchange rate elasticity of Swiss exports will help determine how many percent Swiss exports increase if the Swiss franc depreciates by 1%.

3.1 Theoretical Background

Switzerland is a small open economy with strong economic ties to other countries. During the period 2009-2019, Swiss exports accounted on average for 40% of Switzerland's GDP[2]. The strong export orientation implies that the overall prosperity of the Swiss economy depends on the prosperity of the Swiss export sector (Chen, Watanabe, & Yabu, 2012, p. 13). Due to its geographical proximity, the European Union (EU) is the most important market for Swiss exports. During the period 2009-2019, 55% of total Swiss exports went to the 28 EU countries, whereby the share of exports going to the 19 countries that adopted the euro was 46%[3]. Hence, slightly less than half of the Swiss exports are likely transacted in euros. Switzerland's four most important export partners in the EU during that period were Germany, France, Italy, and the United Kingdom (UK), amounting to 37% of total exports. Germany alone was responsible for purchasing 19% of Swiss exports and is therefore by far the most important export partner for Switzerland. Essential export markets overseas are the US, China and Japan, accounting for 13%, 4% and 3% of Swiss exports, respectively. Overall, the seven countries mentioned above were responsible for purchasing 58% of total Swiss exports from 2009 to 2019. According to the data from the Swiss Federal Customs Administration (SFCA)'s Swiss-Impex database, Switzerland's most important exports by nature of goods during the period of interest were products of the chemical and pharmaceutical industry (42%), watches and precision instruments (21%), machines, appliances and electronics (16%) as well as metals (6%).

The trade literature identified foreign demand and the relative price as the two determinants of exports (Hanslin Grossmann, Lein, & Schmidt, 2016, p. 5549). The demand for Swiss exports is expected to grow when the export partner has more money to spend, which is the case when its GDP grows. On the opposite, the demand for Swiss exports falls when the Swiss franc appreciates against the currency of the trade partner, as Swiss exports become more expensive

[2]Author's calculation with yearly nominal GDP data from the SECO and yearly export data from the SFCA.
[3]Author's calculation based on data from the SFCA's Swiss-Impex database.

(Auer & Sauré, 2011, p. 2). Looking at the evolution of Swiss exports as a percentage of GDP from 2009 to 2019, Graph 3.1 shows that Swiss exports tended to grow despite the strong Swiss franc. The two vertical lines of the graph mark the introduction of the minimum exchange with the euro in September 2011 and its abolishment in January 2015, respectively. From the first line, one can infer that the Swiss exports decreased as the Swiss franc became too strong towards the end of 2011, and this decrease was reverted after introducing the minimum exchange rate with the euro. The second line shows that Swiss exports decreased after abolishing the minimum exchange rate as the Swiss franc initially appreciated strongly. However, in 2016, exports recovered and, apart from a drastic drop at the end of 2018, have overall been growing since then. Hence, while Swiss exports seem to have performed well despite the strong Swiss franc, the drops in export performance before the introduction and after abolishing the minimum exchange rate with the euro indicate a certain sensitivity of Swiss exports to the strength of the Swiss franc. While a visual inspection does not provide strong enough evidence for this assumption, the summary of the empirical literature and the subsequent POLS estimation should allow for more robust conclusions.

Figure 3.1: Swiss Exports as Percentage of GDP from 2009 to 2019

Source: Data from the Swiss Federal Customs Administration and the Swiss State Secretariat for Economic Affairs, author's own depiction.

So far, the focus of this thesis has been on the appreciation of the Swiss franc. However, calculating the prevented export sector damage through the SNB's FXIs requires an analysis of the Swiss exports' reaction to a depreciation of the Swiss franc. That is, this thesis aims to estimate by how much the SNB's FXIs depreciated the Swiss franc compared to a scenario without FXIs, and consequently, how much higher Swiss exports were during the period 2009-2019 due to this depreciation of the Swiss franc, compared to a scenario without FXIs. As can be inferred from the Swiss franc development and safe-haven characteristics discussed in Chapter 2, Switzerland's problem is usually one of an appreciating, not a depreciating Swiss franc. Correspondingly, to the best of the author's knowledge, no literature examines the effect of a depreciation of the Swiss franc on Swiss exports. To still have a point of reference for the subsequent export elasticity estimation, the literature that studies the effect of an appreciation of the Swiss franc on Swiss export performance is briefly summarized.

The literature that studies the effect of the Swiss franc on aggregate exports generally finds no or only a small effect of an appreciation of the Swiss franc on Swiss exports. Thorbecke and Kato (2018, pp. 1187, 1190), for instance, do not find an effect of the exchange rate on aggregate exports for the period 1989-2016, using Johansen maximum likelihood estimation and time series data. However, when they employ a Mark-Sul weighted Dynamic Ordinary Least Squares estimator on panel data from 1989 to 2014, they estimate the real bilateral exchange rate coefficient to be -0.44 and statistically significant at the 1% level. Auer and Sauré (2012, pp. 523-524) investigate the sensitivity of Swiss exports for Switzerland's 27 most important export markets and the 25 largest goods categories using a random effects panel regression covering the period 2005Q1-2010Q3. They find a real bilateral exchange rate coefficient of -0.42, statistically significant at the 5% level. Their finding is in line with Thorbecke and Kato (2018) and implies that an appreciation of the Swiss franc by 10% against a trade partner's currency causes Swiss exports to this trade partner to decrease by 4.2%. The Swiss State Secretariat for Economic Affairs (SECO) estimates the short- and long-run elasticities of aggregate Swiss exports to real bilateral exchange rate movements using an error correction model for the period 1983Q1-2009Q4. They find the short-run elasticity to be lower than the long-run elasticity, estimating a highly significant exchange rate coefficient of -0.4 and -1 for the short- and long-run, respectively (SECO, 2010, pp. 35-36). Hanslin Grossmann et al. (2016, p. 5547) estimate the exchange rate elasticity of Swiss exports for Switzerland's 24 major export destinations and 12 major export sectors using an error correction model on panel data for 1989Q1-2014Q4. For total exports, they find a short-run exchange rate coefficient of -0.17, which is statistically significant at the 5% level. In the long run, their real exchange rate coefficient is -0.65 and statistically significant at the 1% level.

Looking at disaggregate data, Thorbecke and Kato (2018, p. 1184) do not find an effect of the exchange rate on exports from the pharmaceutical and watches industries. However, they find that an appreciation of the Swiss franc negatively affects exports of specialized machinery, machine tools and precision instruments. Lamla and Lassmann (2011, pp. 39-40) estimate the exchange rate elasticity of Swiss exports for 12 export sectors and six countries (Germany, France, Italy, UK, US, and Japan). For the most important export sector (chemicals and pharmaceuticals), they do not find a statistically significant exchange rate coefficient for any of the six countries. For the other two essential export sectors (machinery; precision instruments, watches, and jewellery), they find a modest exchange rate elasticity of Swiss exports, ranging from -0.39 to -2.22. Hanslin Grossmann et al. (2016, p. 5548) find that exports to the two most important sectors (chemicals and pharmaceuticals; precision instruments and watches) do not react strongly to exchange rate movements but are relatively sensitive to long-run developments in foreign demand. Given their findings, they conclude that trends in foreign demand have a stronger effect on Swiss exports than the exchange rate.

Different researchers have come up with an explanation for why the exchange rate elasticity estimates of aggregate Swiss exports are surprisingly low and why Switzerland's most important export sectors are insensitive or react only slightly to changes in the real exchange rate. Lamla and Lassmann (2011, pp. 32-40) argue that Swiss exports' low exchange rate elasticity might be grounded in Switzerland's large share of technologically and qualitatively advanced goods and its specialization in niche products. According to them, these goods are not exposed to price competition because they enjoy market power due to technological advantage or product complexity (e.g. for pharmaceutical products), or the goods are in a high-quality segment which represents a good image or an attractive brand (e.g. luxury watches). Thorbecke and Kato (2018, pp. 1183-1184) note that over 40% of Swiss exports come from the pharmaceutical industry. Since these products are often essential and covered by health insurance, the price elasticity of demand for pharmaceutical products is expected to be low. Based on the Organisation for Economic Co-Operation and Development (OECD) classification of pharmaceutical products and watches as high-technology goods, they calculated that in 2014, 53% of Swiss exports came from the segment of high-technology goods. To put this into context, Germany, France, the US, and the UK have a share of high-technology goods of 20%, 28%, 21% and 24%, respectively. They further calculate two different product sophistication indices comparing Swiss exports with other countries and find that Switzerland had the most sophisticated export structure in the world in most years. Regarding the product sophistication of specific export sectors, they find watches and pharmaceutical products to rank first and third, respectively.

Auer and Sauré (2011, p. 6) investigate two channels - exchange rate sensitivity and export market growth - as possible reasons for the low elasticity of Swiss exports using a panel data set with 24 countries belonging to the OECD and 865 trade sectors on the 4-digit level for the period 1972-2000. They find that in comparison to the other 23 OECD countries in the sample, Swiss exports are exceptional because they are most concentrated in sectors with goods for which the demand changes only little upon an exchange rate movement. In addition, the Swiss export elasticity to foreign GDP seems not to be exceptional compared to the other countries in the sample. In a subsequent study, Auer and Sauré (2011, pp. 521, 526) dig deeper into the particularities of Swiss exports and decompose the sensitivity of Swiss exports into demand and price effects using a sample of 27 countries and 25 goods for the period 2005Q1-2010Q3. Using this method, they find that the strength of the Swiss franc harmed Swiss exports during their investigation period. In addition, they also find that the reason for the strong Swiss export performance despite the strong Swiss franc was that the appreciation of the Swiss franc coincided with a substantial recovery of global demand. They conclude that a failure to account for the coincidence between the Swiss franc appreciation and global demand recovery might lead to the misconception that the Swiss export performance is not influenced by the exchange rate.

Summarizing these findings from the literature, Switzerland's most important export sectors seem to be relatively insensitive to the price elasticity of demand due to their product sophistication. While a strong Swiss franc objectively does not seem to affect the aggregate export volume negatively, one needs to be aware of possible strong positive demand effects that offset the adverse price effects. The literature just summarized focused on the impact of an appreciation of the Swiss franc on Swiss exports. However, the question of interest is the effect that a depreciation of the Swiss franc has on aggregate Swiss exports. Assuming that the magnitude is the same while the sign differs (the validity of this assumption will be proven in Chapter 3.2.2), a depreciation of the Swiss franc is expected to positively affect the volume of Swiss exports, although with a small magnitude, and not to have any effect on Switzerland's most important export sectors - pharmaceutical products and watches. It is worth pointing out that the above literature review focused on the impact of an appreciation of the Swiss franc on Swiss exports without considering the effect on imports. Given that an appreciating Swiss franc lowers the price of imports, Swiss exporters could partially offset the loss in exports resulting from the stronger Swiss franc through the gains from the cheaper imports of raw materials. Due to the limited scope of this thesis, the aspect of cheaper imports is not further considered. Instead, the inclusion of the import side in the cost-benefit analysis should be regarded as a potential next step after this thesis.

3.2 Pooled Ordinary Least Squares Estimation

A POLS estimator was used to investigate the exchange rate elasticity of total Swiss exports and exports disaggregated by sector. The focus lies on the effect of a depreciation of the Swiss franc on the volume of Swiss exports. The aim is to estimate how much Swiss exports increase if the Swiss franc depreciates by 1%. The elasticities were estimated over the period 2009-2019 using quarterly data and a sample of countries that were, on average, the primary purchasers of Swiss exports, accounting for 70% of Switzerland's total exports during that period. These countries are Austria, China, France, Germany, Hong Kong, Italy, Japan, the Netherlands, Spain, the United Kingdom, and the United States. Hence, the panel dataset includes 11 panels and 44 periods and a total of 484 observations.

3.2.1 Data and Methodology

Quarterly data on exports in CHF was obtained from the Swiss-Impex database of the SFCA. The exports were transformed to million CHF and deflated using the Swiss franc export unit value index received upon request from the SFCA. Quarterly data on the real bilateral exchange rate between each importing country and Switzerland were constructed using the nominal bilateral exchange rate between each country and Switzerland vis-à-vis the euro area and the Consumer Price Index (CPI) of each country, including Switzerland. The data were obtained from the International Monetary Fund (IMF)'s International Financial Statistics (IFS) database.

An increase in the exchange rate represents a depreciation of the Swiss franc. Quarterly seasonally adjusted data on real GDP were also taken from the IMF's IFS database. The data, denominated in millions of the domestic currency, were converted to million Swiss francs using the constructed nominal exchange rate between the importing countries and Switzerland. There were no quarterly data available for China. Therefore, yearly data was taken from the French Center for Research and Expertise on the World Economy (CEPII-CHELEM) database and transformed into quarterly data using a cubic spline interpolation. The reader is referred to Appendix 1 for a detailed description of the variables and Table 6.2 in Appendix 2 for the summary statistics of the variables.

The data were tested for unit roots using the Levin, Lin, and Chu (2002) and the Im, Pesaran, and Shin (2003) tests. The test results, found in Appendix 2, were mixed but indicate that some variables are non-stationary. The same tests with the first difference of the variables revealed that those variables containing a unit root are stationary after first-differencing. Since first differencing yields stationary and uncorrelated errors (Wooldridge, 2010, p. 317), the first difference of all variables was used. A Chow test was conducted to check whether the data were poolable. The results indicated that the data are stable, i.e. the same coefficients apply across all countries. After having established the homogeneity assumption over the coefficients, the Honda (1985) and the Breusch and Pagan (1980) tests were used to check whether individual effects are present in the data, i.e. whether there is individual heterogeneity and hence, a different intercept should be used for every country. Both tests rejected the presence of individual effects, indicating that the POLS estimator should be preferred over a random or fixed effects estimator (Croissant & Millo, 2008, p. 3). The POLS pools the observations across countries and time and runs an OLS on these pooled observations (Wooldridge, 2010, p. 150). Given that the first difference of the variables was used, the POLS estimation applied to this specific setting is equivalent to a first difference estimator, an OLS estimator used on differenced data (Croissant & Millo, 2018, p. 122). The estimated model from Equation 3.1 is based on the two determinants of exports identified in the literature – relative prices captured by the real bilateral exchange rate and foreign demand captured by real GDP.

$$\Delta ex_{i,j,t} = \beta \Delta rer_{j,t} + \gamma \Delta {y_{j,t}}^* + \Delta \epsilon_{i,j,t}, \quad t = 1, ..., T; \quad j = 1, ..., N \tag{3.1}$$

The variable $\Delta ex_{i,j,t} = log(ex_{i,j,t}) - log(ex_{i,j,t-1})$ denotes real exports from Switzerland to country j, $\Delta rer_{j,t} = log(rer_{j,t}) - log(rer_{j,t-1})$ is the real bilateral exchange rate between the importing country j and Switzerland, $\Delta {y_{j,t}}^* = log({y_{j,t}}^*) - log({y_{j,t-1}}^*)$ represents the real GDP in country j, and $\Delta \epsilon_{i,j,t} = \epsilon_{i,j,t} - \epsilon_{i,j,t-1}$ is the error term. The subscript i distinguishes between the total real exports and the sectoral real exports, respectively. The log of the variables was used to make them more normally distributed and give the coefficients a percentage interpretation (Wooldridge, 2018, p. 45). β is the coefficient of interest and is expected to be positive. If the real bilateral exchange rate between the importing country and Switzerland increases (i.e. the Swiss franc depreciates), the real exports to that country are expected to increase.

A battery of tests was performed to check the behaviour of the error terms. The serial correlation tests yielded mixed results. While the Durbin and Watson (1950) test did not find a serial correlation to be present, the Breusch-Godfrey test (Breusch (1978); Godfrey (1978)) as well as the Wooldridge (2010, pp. 282-283) first-difference test for serial correlation in panels detected serial correlation in the error term. The Breusch and Pagan (1979) test detected heteroskedasticity, and the Pesaran (2004) test cross-sectional dependence in the error terms. The latter, for instance, arises when countries respond to common shocks (Croissant & Millo, 2018, p. 104). To ensure valid statistical inference, the spatial correlation consistent (SCC) standard errors of Driscoll and Kraay (1998) were used, which are robust to heteroskedasticity, serial correlation, as well as general forms of spatial and temporal dependence (Hoechle, 2007, p. 282).

The sectoral exchange rate elasticity of Swiss exports was estimated for capital goods, consumption goods, non-pharmaceutical products, pharmaceutical products, and watches[4]. The choice of sectors and categories follows the one of Thorbecke and Kato (2018, p. 1189). However, since the data were obtained from a different source (the SFCA's Swiss-Impex database), the composition of categories might differ slightly from their composition.

3.2.2 Results

Table 3.1 reports the results that were obtained from the POLS estimation with the 11 countries that purchase most exports from Switzerland. The first column shows the coefficients for aggregate exports, which are of most interest. The real bilateral exchange rate coefficient is 0.24 and statistically significant at the 1% level. This implies that a 10% depreciation of the Swiss franc relative to the currencies of its export partners causes Switzerland's exports to increase by 2.4%. Looking at the exchange rate elasticities of the individual export sectors, all of them are statistically significant, although at different levels. Pharmaceutical products seem to react the strongest – a 10% depreciation of the Swiss franc increases pharmaceutical exports by 4.6%. The statistical significance of this result is surprising, given that the literature identified pharmaceutical products as insensitive to exchange rate movements due to their product sophistication. In terms of magnitude, the other sectors are ranked in decreasing order as capital goods (0.38), non-pharmaceutical products (0.23), and consumption goods (0.13). The exchange rate coefficient of watches is -0.26 and statistically significant at the 5% level. This is remarkable because, according to the literature, the demand for watches should not react in a statistically significant way to exchange rate movements.

[4]Capital goods come from the following categories and subcategories of the SFCA's Swiss-Impex database: air - & spacecraft, agricultural machines, military equipment, road vehicles, precision instruments & equipment, watercraft, electrics & electronical industry appliances & devices, construction machines and office machines. Consumption goods come from the following categories: beverages, road vehicles, horticultural products, plant-based prepared or processed food, animal-based prepared or processed food, outer clothing, undergarments, clothing accessoires, pharmaceuticals, domestic machines, consumer electronics, optical instruments, watches, toys & sports equipment and exposed film. Non-pharmaceuticals were calculated by subtracting real exports in the pharmaceuticals sector from total real exports.

Table 3.1: Pooled OLS Estimation of Case 1

	All goods	Capital goods	Consumption goods	Pharmaceuticals	Watches	Non-pharmaceuticals
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	0.04	0.02	0.08	-0.05	0.18	0.04
	(0.19)	(0.27)	(0.18)	(0.28)	(0.26)	(0.21)
Bilateral Real Exchange Rate	0.24***	0.38***	0.13*	0.46**	-0.26**	0.23***
	(0.07)	(0.11)	(0.07)	(0.21)	(0.11)	(0.05)
Real GDP	0.30***	0.43***	0.25**	0.62**	0.10	0.26***
	(0.11)	(0.14)	(0.10)	(0.28)	(0.11)	(0.07)
N	440	440	440	440	440	440
R^2	0.57	0.55	0.37	0.54	0.49	0.53

*Notes: * p < 0.1, ** p < 0.05, *** p < 0.01.* An increase in the real bilateral exchange rate represents a depreciation of the CHF.

Due to the absence of empirical literature studying the effect of a depreciation of the Swiss franc on Swiss exports, the above results are difficult to contextualize. To assess whether the impact on Swiss exports found for a depreciating Swiss franc can be compared with the literature that examines the effect of an appreciating Swiss franc, the same POLS estimation was conducted using the exchange rate where an increase represents an appreciation of the Swiss franc. For clarity, the term “Case 1” will be used when talking about the scenario of interest, i.e. where an increase of the exchange rate represents a depreciation of the Swiss franc. In contrast, “Case 2” refers to the scenario used for benchmarking with the literature, i.e. where an increase of the exchange rate refers to an appreciation of the Swiss franc. The estimation of Case 2 is similar to the previous estimations conducted in the literature, and the results are therefore directly comparable. If the Case 2 estimation coefficients turn out to be of the same magnitude (but different sign) as those of the Case 1 estimation, the conclusions drawn from the comparison of the Case 2 estimation with the literature also hold for Case 1.

Table 3.2 displays the results obtained from the POLS estimation using the real bilateral exchange rate where an increase represents an appreciation of the Swiss franc. The only thing that has changed compared to the Case 1 estimation in Table 3.1 is the real bilateral exchange rate. Comparing the coefficients of the real bilateral exchange rate of Case 1 (increase = depreciation of the CHF) with the ones of Case 2 (increase = appreciation of the CHF), the magnitudes of the coefficients are very similar, while the signs are expectedly different. The statistical significance is the same for all sectors except for consumption goods and pharmaceutical products. There is no statistically significant effect for consumption goods, implying that an appreciation of the Swiss franc does not affect the volume of exports in the consumption goods sector. The coefficient of pharmaceutical goods is now only statistically significant at the 10% level. While this is in contrast to the expectation formed based on the findings in the literature, it is weaker than the 5% significance level that was found for Case 1. The coefficient for watches still shows a statistical significance level of 5%, which contrasts with the findings in the literature. The conclusions drawn from the comparisons of Case 1 and Case 2 are that the magnitude of the coefficients is the same. At the same time, consumption goods and pharmaceutical products seem to react differently depending on whether the Swiss franc appreciates or depreciates. To be more precise, consumption goods only respond to a depreciation of the Swiss franc, while pharmaceutical products are more certain to react to a depreciation than an appreciation of the Swiss franc. The similar magnitude of the coefficients suggests that the conclusions drawn about the magnitude of the exchange rate elasticity of Swiss exports based on the comparison of the Case 2 results with the literature are also valid for the estimates of Case 1.

Table 3.2: Pooled OLS Estimation of Case 2

	All goods	Capital goods	Consumption goods	Pharmaceuticals	Watches	Non-pharmaceuticals
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	0.04	0.02	0.08	-0.05	0.18	0.04
	(0.20)	(0.28)	(0.19)	(0.29)	(0.26)	(0.21)
Bilateral Real Exchange Rate	-0.22^{***}	-0.35^{***}	-0.12	-0.41^{*}	0.25^{**}	-0.22^{***}
	(0.07)	(0.11)	(0.07)	(0.21)	(0.10)	(0.05)
Real GDP	0.30^{***}	0.43^{***}	0.25^{**}	0.60^{**}	0.10	0.25^{***}
	(0.11)	(0.14)	(0.11)	(0.29)	(0.11)	(0.08)
N	440	440	440	440	440	440
R^2	0.55	0.53	0.35	0.51	0.49	0.51

*Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.* An increase in the real bilateral exchange rate represents an appreciation of the CHF.

The Case 2 coefficient of the real bilateral exchange rate for aggregate exports is -0.22 and statistically significant at the 1% level. This implies that a 10% appreciation of the Swiss franc reduces aggregate Swiss exports by 2.2%. The estimate is lower than the coefficients estimated by Auer and Sauré (2012, p. 524), Thorbecke and Kato (2018, p. 1190), and the short-run estimate of the SECO (2010, pp. 35-36), who estimate a coefficient of -0.42, -0.44 and -0.4 respectively. It is, however, very close to the short-run estimate by Hanslin Grossmann et al. (2016, p. 5547), who find an exchange rate coefficient of -0.17.

One possible reason for the difference in the findings of most of the literature could be the different periods under investigation. In the literature, most of the authors start their research back in the 1980s, which implies that they not only incorporate a longer period, but their estimation also partly includes a very different economic setting. Due to higher trade tariffs, trade costs were considerably higher in the 1980s compared to the 2010s (Tsubuku, 2016, p. 118). Thus, an appreciation of the Swiss franc likely caused a stronger reaction in the quantity of exports demanded in a less globalized setting due to the higher trade barriers. In a more globalized world, trade costs are lower while the opportunities for substituting one product with another are larger. It seems, at first sight, puzzling that the demand for Swiss exports should react less to an appreciation of the Swiss franc compared to the same scenario in a less globalized world, given the larger substitution possibilities. However, the finding by Thorbecke and Kato (2018, pp. 1183-1184) that Switzerland has the most sophisticated exports in the world suggests that purchasers of Swiss exports do not have a lot of substitution possibilities available. Therefore, the lower trade costs might be a reason for the lower exchange rate sensitivity of Swiss exports today compared to the 1980s, suggesting that the different periods under investigation might explain the lower estimate found compared to the literature.

Another possible reason for the lower coefficient obtained in the estimation of Case 2 compared to the literature might be the higher share of total exports covered by the sample used for the POLS estimation. While most of the authors do not mention which share of total exports their sample covers, Auer and Sauré (2012, p. 524) report their sample to comprise 40.5% of Switzerland's total exports. Comparing this to the 70% of total exports covered by the sample used for this thesis suggests that focusing on a too small part of total Swiss exports might overestimate the aggregate effect that an appreciation of the Swiss franc has on the volume of Swiss exports.

For comparing the sectoral estimates in Case 2 with those from the literature, the point of reference is Thorbecke and Kato (2018, p. 1190), as the export sectors were selected along their lines. Comparing the sectoral coefficients in terms of magnitude and sign, the coefficients estimated in Case 2 are similar to those estimated by Thorbecke and Kato (2018, p. 1190). Capital goods exports seem to react the strongest by an appreciation of the Swiss franc, followed by non-pharmaceutical goods, consumption goods and watches. Pharmaceutical goods form the exception, as Thorbecke and Kato (2018, p. 1190) rank their reaction between consumption goods and watches. This implies that the estimation at hand might overestimate the reaction of pharmaceutical goods to an appreciation of the Swiss franc, given that it ranks their reaction the strongest among all sectors. The different results compared to Thorbecke and Kato (2018, p. 1190) might, for instance, result from the fact that a different dataset and a different period were used. Hence, the classification of pharmaceutical products might not be the same or the price elasticity of certain products might have changed over time.

Comparing the coefficients of the individual export sectors, the coefficients estimated for Case 2 generally match those by Thorbecke and Kato (2018, p. 1190) quite closely or underestimate them a bit. However, there are differences in terms of statistical significance. Thorbecke and Kato (2018, p. 1190) estimate a capital goods coefficient of -0.61, statistically significant at the 1% level. This compares to a Case 2 coefficient of -0.35 at the 1% statistical significance level. For non-pharmaceutical products, the coefficient of Thorbecke and Kato (2018, p. 1190) is -0.36 and compares to a coefficient of -0.22 from Case 2, both estimates being statistically significant at the 1% level. Interestingly, the coefficient of watches is the closest to Thorbecke and Kato (2018, p. 1190) among all export sectors, comparing 0.23 by Thorbecke and Kato (2018, p. 1190) with an estimate of 0.25 from Case 2. However, while Thorbecke and Kato

(2018, p. 1190) could not find any statistical significance for this coefficient, the coefficient in Case 2 is statistically significant at the 5% level. The fact that the coefficient of watches is the only positive coefficient suggests that watches might be a Veblen good, i.e. a status symbol for which demand increases as the price goes up. The statistically significant coefficient of watches in the case at hand could be explained by the increasing importance of status symbols in the period under investigation, for example, due to the widespread use of social media, as compared to the period under investigation by Thorbecke and Kato (2018), which spans from 1989 to 2014. Regarding pharmaceutical goods, Case 2 seems to overestimate the effect, comparing a coefficient of -0.41 with a coefficient of -0.27 by Thorbecke and Kato (2018, p. 1190) and a statistical significance level of 10% with no statistical significance, respectively. Lastly, the statistically insignificant Case 2 estimation of 0.12 for consumption goods is quite different from the coefficient of -0.32 by Thorbecke and Kato (2018, p. 1190), which is statistically significant at the 1% level.

The most important takeaway from the comparison with the literature is that apart from consumption goods, all estimates in Case 2 have a reasonable sign and magnitude, supporting the notion that the estimate for aggregate exports is plausible. However, as was the case with the coefficient for aggregate exports, most sectoral coefficients estimated for Case 2 are lower than those found in the literature. As explained earlier, possible reasons could be the different periods under investigation and the lower share of total exports covered in the case at hand. The comparison with the literature further revealed that capital goods seem to show the strongest negative reaction to an appreciation of the Swiss franc and that the results found in Case 2 for pharmaceutical products should be viewed with caution. The above conclusions imply that the sign and magnitude of the coefficients estimated for Case 1 are reasonable. Thus, the real exchange rate coefficient for aggregate exports obtained for Case 1 can be confidently used to calculate the prevented export sector damage that the SNB achieved through its FXIs. Having investigated both the scenarios of a depreciating and an appreciating Swiss franc and comparing the findings with the literature, one can further conclude that exports react similarly regardless of the direction of the exchange rate movement except for pharmaceutical products and consumption goods. For the two exceptions just mentioned, the results must be viewed with caution as they are contrary to the theoretical expectation.

3.3 Robustness Checks

The robustness of the above results was investigated in two different ways. In a first step, it was tested whether the POLS estimation yielded the same results for Case 1 when more countries were included. The expanded dataset represents 80% of Switzerland's total exports and consists of the countries from the original dataset plus Australia, Belgium, Brazil, Canada, Poland, Russia, and Singapore. Some data availability issues marked the construction of this dataset. According to the ranking of countries in terms of the average share of total exports during the period 2009-2019, the United Arab Emirates and South Korea would also have to be included in the expanded dataset. However, this was not possible because the necessary data were lacking for the United Arab Emirates. At the same time, South Korea had to be excluded because the South Korean Won (KRW)/CHF exchange rate was so small that the estimation tended to infinity. Furthermore, there was an issue with the availability of quarterly real GDP data for Russia. Therefore, yearly real GDP data from the CEPII-CHELEM database was transformed to quarterly data using a cubic spline interpolation, as done for China in the original dataset. The expanded dataset includes 18 panels and 44 periods, and a total of 792 observations.

Table 3.3 displays the results of the POLS estimation for Case 1 with the expanded dataset. The real bilateral exchange rate coefficient for aggregate exports is 0.23 and statistically significant at the 1% level. Comparing this with a coefficient of 0.24 estimated for the original dataset, one can conclude that the estimation of the exchange rate elasticity for aggregate exports is robust to the inclusion of more countries. The fact that the coefficient is slightly lower when more countries are included supports the earlier notion that a sample representing a too small share of total exports might overestimate the effect.

Table 3.3: Pooled OLS Estimation of Case 1 with Expanded Dataset

	All goods	Capital goods	Consumption goods	Pharmaceuticals	Watches	Non-pharmaceuticals
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	0.10	0.07	0.09	0.04	0.13	0.12
	(0.15)	(0.18)	(0.15)	(0.14)	(0.27)	(0.18)
Bilateral Real Exchange Rate	0.23^{***}	0.36^{***}	0.17^{***}	0.43^{***}	-0.13	0.20^{***}
	(0.06)	(0.08)	(0.06)	(0.15)	(0.10)	(0.06)
Real GDP	0.29^{***}	0.43^{***}	0.30^{***}	0.65^{***}	0.07	0.19^{**}
	(0.07)	(0.10)	(0.05)	(0.19)	(0.18)	(0.08)
N	748	748	748	748	748	748
R^2	0.44	0.49	0.40	0.59	0.09	0.23

*Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.* An increase in the real bilateral exchange rate represents a depreciation of the CHF.

Looking at the coefficients of the sectoral exports, this pattern is confirmed for all sectors except consumption goods, for which the real exchange rate coefficient using the expanded dataset is higher (0.17) than in the original estimation of Case 1 (0.13). The real exchange rate coefficient of watches is not statistically significant anymore, hence, in line with the literature. However, the statistical significance of pharmaceutical goods' real exchange rate coefficient increased from 5% to 1%, contrasting with the absence of statistical significance found in the literature. In summary, including more countries in the estimation confirms the results found in the original Case 1 estimation for aggregate exports. The sectoral export estimations also seem robust and more in line with the literature. However, while the estimate for pharmaceutical products is in line with the original estimation of Case 1, it is still in contrast to what has been found in the literature and should therefore be viewed with caution.

In a second step, it was tested whether the results estimated for Case 1 were robust to a relaxation of the homogeneity assumption, which was implicitly made when using the POLS estimator. The POLS estimator was chosen as the preferred method because the Honda (1985) and the Breusch and Pagan (1980) tests indicated that the same intercepts should be used for all countries. However, given that the dataset includes countries from different geographical locations, it is hard to believe that there is no heterogeneity present in the dataset. Therefore, accounting for the possibility that some heterogeneity could not be detected by the tests mentioned above, the Hausman (1978) test was conducted to identify whether this heterogeneity would be of a random or fixed effects nature. The results suggest that a random effects model should be used, meaning that the unobserved effect causing the heterogeneity is not correlated with the explanatory variables. Due to the absence of correlation with the independent variables, a random effects model puts the unobserved effect into the error term. Given that the POLS estimator also puts the unobserved effects into the error term, a random effects model can technically be estimated using a POLS estimator (Wooldridge, 2010, pp. 252-257). Therefore, one would expect that the POLS estimator and the estimation of random effects yield the same results. Table 6.4 in Appendix 2 demonstrates that conducting the Case 1 estimation with the original dataset using a random effects model instead of a POLS model yields the same results as in the POLS estimation. Hence, one can conclude that the results received for the Case 1 estimation are robust to the use of heterogeneous effects.

Going one step further, even if the Hausman (1978) test would have wrongly identified the unobserved effect as a random effect, while in reality, it is a fixed effect, using a POLS estimator with the first difference of the variables would be the appropriate choice. According to Wooldridge (2010, p. 284), when $T > 2$ and the error term follows a random walk, the first difference estimator should be preferred over the fixed effects estimator. The fact that the Levin et al. (2002) and the Im et al. (2003) tests detected non-stationarity of the variables implies that they follow a random walk. Hence, even when the underlying data structure would be of a fixed effects nature, the first difference estimator using POLS should be chosen to estimate the fixed effects model because the variables in the dataset are non-stationary (Wooldridge, 2010, p. 317). In conclusion, the robustness checks showed that the findings are robust to including more countries and allowing for heterogeneous effects. In addition, even if the conducted tests delivered wrong results, the chosen estimation method would be the preferred one due to the presence of unit-roots.

4 The Effect of the Swiss National Bank's Foreign Exchange Interventions

After having estimated the real exchange rate elasticity of aggregate Swiss exports in the previous chapter, this chapter contains the second step of the calculation, namely the estimation of the FXI elasticity of the Swiss franc. Putting the estimate from the previous chapter and the one of this chapter together will eventually allow calculating the overall damage that would have occurred to the Swiss export sector in the absence of the SNB's FXIs. This chapter first sets out the theoretical background of foreign exchange interventions. Subsequently, it estimates the effect of the SNB's FXIs on the CHF/EUR exchange rate from 2009 to 2019 using a 2SLS estimation. In the last step, the robustness of the results will be examined.

4.1 Theoretical Background

As mentioned in Chapter 2, foreign exchange intervention denotes the practice of central banks buying and selling currency in the foreign exchange market to affect the domestic exchange rate (Neely, 2005, p. 685). Typically, FXI activity is sterilized by offsetting the change in the money supply occurring through the purchase or sale of currencies by an immediate open market operation. If the change in the money supply is not offset, the FXI is called unsterilized (Vitale, 2007, p. 155). While the latter clearly influences the exchange rate, the literature has fallen short of reaching a definitive conclusion about the effects of sterilized FXI, frequently suggesting the absence of any relation (e.g., Sarno and Taylor (2001) or Dominguez and Frankel (1993)). Given the disagreement about its effectiveness, most empirical studies focus on the effect of sterilized FXIs. While there are a few studies about unsterilized FXIs in Japan (see e.g. Iwata and Wu (2012)), it seems more appropriate to focus on the sterilized FXI strand of literature because the potential absence of any effect fostered the use of more sophisticated estimation methods. Given the general acceptance of the effectiveness of unsterilized FXIs and the finding that unsterilized FXIs have a more significant impact on the exchange rate than sterilized FXIs (Iwata & Wu, 2012, p. 430), it can be reasonably assumed that the methods applied to a setting of sterilized FXIs can also be used for estimating the effect of unsterilized FXIs or, as it seems for Switzerland, the impact of a mixture between sterilized and unsterilized FXIs.

Researchers have focused on three types of studies to investigate a possible relationship between sterilized FXI and the exchange rate. The most frequently used type is time series event studies, which examine the effect of an intervention on returns with a single equation using intervention and a few regressors to explain the change in the exchange rate. The second type of event study uses data only from around periods of intervention, ignoring the behaviour of exchange rates when there is no intervention. Lastly, studies with high-frequency data aim at better understanding the behaviour of exchange rates immediately around the intervention. The problem with event studies is their inherent endogeneity. Because intervention quickly reacts to exchange rate movements, exchange rates and intervention are likely determined simultaneously (Neely, 2005, pp. 685-689). Using high-frequency data reduces unwanted effects from endogeneity due to the narrow observation window. However, the short analysis period leaves an open question about the persistency of the impact over time (Daude, Levy-Yeyati, & Nagengast, 2016, p. 241).

In contrast to the academic disagreement regarding the effectiveness of sterilized FXI, there exists a remarkable consensus among central bankers. In a survey of central bankers conducting interventions, Neely (2001, p. 7) found unanimous support for the idea that FXI effectively changes exchange rates. While the SNB's situation is different from that of most other central banks due to its strong focus on unsterilized FXIs, the fact that the SNB is relying heavily on FXIs suggests that its central bankers believe in its effectiveness. This thesis aims neither to question this stance nor to dig deeper into the question of the point of sterilized versus unsterilized FXI. Instead, the goal is to find the best estimate of the effect of FXI on the exchange rate, accounting for the previously described endogeneity problem. The instrumental variables approach is the most common procedure for eliminating the problem of endogeneity caused by simultaneity. The method consists of finding an instrument for FXI, i.e. a variable correlated with FXI but uncorrelated with the exchange rate, and performing a 2SLS estimation (Wooldridge, 2010, p. 89).

While the focus of this thesis does not lie on whether FXI is effective, the empirical findings are of interest because they provide a benchmark for the author's 2SLS estimation. The empirical literature on the effect of the SNB's FXIs is scarce and difficult to compare with the setting at hand. Because the SNB only published FXI data with exact intervention times from 1986 to 1995, most studies about the effect of the SNB's interventions focus on this timeframe. For instance, Payne and Vitale (2003, p. 333) examined the effect of the SNB's spot purchases and sales of the USD on the USD/CHF exchange rate using a transaction-level data set. They found that the investment of USD 50 million has an immediate impact of almost 30 basis points on the USD/CHF exchange rate (Payne & Vitale, 2003, p. 341).

However, in the opinion of the author, given that the monetary setting was substantially different from that after the global financial crisis in 2008, for instance, due to the absence of negative interest rates and lower levels of current and capital account openness in the former period, these studies do not provide a solid basis for comparison. Therefore, more recent studies with an international focus are taken as a point of reference, accepting the disadvantage that most studies focus on the bilateral exchange rate with the USD instead of the EUR. Using a panel of 35 emerging market and advanced economies for the period 1990Q1-2013Q4, Blanchard, Adler, and de Carvalho Filho (2015, p. 16) estimated that an intervention of 1 percentage point of GDP has a short-run effect on the exchange rate of around 1.5%. Adler, Lisack, and Mano (2019, pp. 2, 8-9) estimated the effect of FXI on the exchange rate of the USD vis-à-vis the local currency for a panel dataset of 52 countries during the period 1996-2013. They found a positive FXI of 1 percentage point of GDP to depreciate the real bilateral exchange rate by 1.4-1.5% and the nominal bilateral exchange rate by 1.7-1.9%. Given that these studies focus on a broad set of countries, the findings likely represent the effect of sterilized FXIs. Analyzing the case of Japan, Iwata and Wu (2012, p. 430) found unsterilized FXIs to have a larger effect than sterilized FXIs. Hence, the result found as part of the subsequent 2SLS estimation is expected to be larger than the one found in the literature.

4.2 Two-Stage Least Squares Estimation

The instrumentation strategy relies on an approach that differs from most of the existing literature, using comparatively low-frequency monthly data, which has the advantage of adopting a broader macroeconomic focus (Adler et al., 2019, p. 2). Recently, several papers have relied on a low-frequency data approach using instrumental variables to overcome the endogeneity problem. These include Adler et al. (2019), who estimate the effect of FXI on the exchange rate for a panel of 52 emerging and advanced economies; Blanchard et al. (2015), who examine the effect of FXI in the presence of capital flow shocks; Phillips et al. (2013), who focus on the determinants of exchange rates but do not specifically consider FXI; and Daude et al. (2016), who examine the effect of FXI on exchange rates in emerging markets. The estimation conducted as part of this thesis follows the line of Adler et al. (2019), but given the one-country setting, time series instead of panel data were used, which puts the estimation back on an equal footing with most of the existing literature. In line with the literature, the instrumentation relies on variations in FXI related to Switzerland's precautionary motives for accumulating or decumulating reserves, which will be captured by standard metrics of reserve adequacy (Adler et al., 2019, p. 2).

4.2.1 Data and Methodology

The data used are monthly time series for the period 2009 to 2019, coming from Adler, Chang, Mano, and Shao (2021), the IMF's IFS, the OECD, the SFCA, the SNB, the SECO, as well as Datastream. All data are in trillion CHF. Unit roots were tested using the Augmented Dickey-Fuller test, and first differencing was applied to all variables to ensure that they are stationary at the same order of integration. Using first differences also has the advantage of removing any linear time trend. The disadvantage is that the coefficients have a change instead of a level interpretation. A detailed description of all variables and their transformation can be found in Appendix 1. The model was tested for serial correlation and heteroskedasticity of the error terms using the Durbin-Watson and Breusch and Pagan (1979) tests. Given that they detected autocorrelation and heteroskedasticity, Newey-West heteroskedasticity and autocorrelation consistent standard errors were used (Wooldridge, 2018, pp. 382-400, 612).

For the first stage of the 2SLS estimation, FXI was regressed on a series of control variables and instruments, specified as

$$\Delta\, FXI_t = a + \boldsymbol{b'_m \Delta Z_{tm}} + \boldsymbol{c'_k \Delta X_{tk}} + v_t \tag{4.1}$$

$\boldsymbol{Z_{tm}}$ denotes the set of instrumental variables and $\boldsymbol{X_{tk}}$ is the set of regressors expected to drive exchange rate variations at time t. The error term of the first-stage regression is denoted as v_t.

The second-stage regression specification is the following:

$$\Delta\, log(ER_t) = \alpha + \beta \Delta \widehat{FXI_t} + \boldsymbol{\gamma_k'} \boldsymbol{\Delta X_{tk}} + u_t \tag{4.2}$$

Equation 4.2 links Switzerland's real bilateral exchange rate at time t (ER_t) to the instrumented FXI and a series of exchange rate determinants ($\boldsymbol{X_{tk}}$). Given that the focus of the estimation lies on the effect that FXI has on the exchange rate, β is the parameter of interest. A negative value of β implies that a positive intervention depreciates the Swiss franc. u_t denotes the error term of the second-stage regression. The exchange rate is defined as CHF/EUR, and an increase represents an appreciation of the Swiss franc. The reason for focusing on the CHF/EUR exchange rate lies in the safe-haven characteristics of the Swiss franc. According to Grisse and Nitschka (2015, p. 160), the Swiss franc shows safe-haven characteristics relative to the EUR but not the USD. Data from the SFCA's Swiss-Impex database indicates that the EU is the largest trading partner of Switzerland, accounting for 55% of its total trade during the period 2009-2019. These close ties and the fact that a safe-haven currency provides a hedge during periods of global financial distress suggest that turmoil is associated with increased capital flows from the EU towards Switzerland, causing the Swiss franc to appreciate (Cavallino, 2019, p. 153). The introduction of the minimum CHF/EUR exchange rate in September 2011 to prevent a further massive appreciation of the Swiss franc supports the notion that the SNB's focus of intervention lies on the CHF/EUR, not the CHF/USD exchange rate.

FXI_t denotes the proxy for foreign exchange intervention, which is used because the SNB does not publish actual monthly data on the amount of its FXIs. The most popular strategy to date is using foreign exchange reserves data as a proxy for FXI (Neely, 2000, p. 17). However, creating a good proxy based on reserves data is challenging since the lack of data obscures the extent to which the change in foreign reserve assets also includes interest income or valuation changes (Hüfner, 2003, p. 87). Adler et al. (2021, pp. 7, 14-16) tried to remedy this problem by constructing a dataset which includes spot and derivative transactions that have been adjusted for valuation changes, investment income, other foreign currency assets and liabilities vis-à-vis nonresidents, and foreign currency assets and liabilities vis-à-vis residents. They measured the performance of their proxy by comparing it to commonly used measures of FXI for countries that have published FXI data and found their proxy to be closer to the actual data than the conventional FXI proxies. Knowing that their proxy is the best option available at the time of writing this thesis, it was used for the estimation at hand. To prevent endogeneity that might arise from movements in the CHF value of nominal GDP, the FXI variable was normalized by Switzerland's GDP (Adler et al., 2019, p. 4).

The control variables $\boldsymbol{X_{tk}}$ were split into a small set and an expanded set to keep the baseline specification as parsimonious as possible. The small set of controls consists of the Euro STOXX 50 Volatility Index (VSTOXX), three commodity price indices for energy, metal and food, the interest rate differential with the Euro Area (EA), and the trade balance. The VSTOXX is an equity volatility index used to measure global risk aversion, i.e. the fear existing among investors. Given the safe-haven characteristics of the Swiss franc, the demand for Swiss assets should increase during periods of strong fear (Cavallino, 2019, pp. 152-153). The commodity price indices capture possible terms of trade shocks, which measure the purchasing power of exports relative to imports, representing the changes in relative prices of Switzerland's foreign trade (Gantman & Dabós, 2018, p. 95). The interest rate differential vis-à-vis the EA accounts for the fact that the focus lies on the bilateral exchange rate with the EUR and controls for the effect of simultaneous changes in the interest rate on the exchange rate (Adler et al., 2019, p. 6). Finally, the trade balance was included to capture Switzerland's trade dependence. A trade balance deterioration is expected to appreciate the exchange rate (Gantman & Dabós, 2018, pp. 94-95). The variable was lagged to strengthen its exogeneity. When conducting robustness checks with the nominal bilateral exchange rate, the inflation differential with the EA was also added to the small set of control variables, as the exchange rate could show movements reflecting persistently high levels of inflation (Adler et al., 2019, p. 6).

The expanded set of controls consists of the GDP per capita differential with the EA, a measure of trade openness, and the ratio of capital flows over GDP. The GDP per capita differential aims at capturing income effects which might appreciate the Swiss franc (Griffoli, Meyer, Natal, & Zanetti, 2015, p. 6). Trade openness is measured as imports plus exports over GDP. It captures the degree to which Switzerland is exposed to currency crises and sudden stops to capital inflows, which are expected to be less frequent the more open the economy (Cavallo & Frankel, 2008, p. 1445). Lastly, capital flows were included to capture the increase in foreign demand for Swiss assets caused by the safe-haven characteristics of the Swiss franc. Cavallino (2019, p. 129) found that the Swiss franc appreciates by six percentage points in nominal terms and three percentage points in real terms when the foreign demand for Swiss assets increases by 16% of GDP.

The set of instrumental variables $\boldsymbol{Z_{tm}}$ was used to ensure that FXI_t in Equation 4.2 is exogenous. To have a valid instrument, two assumptions need to be fulfilled (Wooldridge, 2010, pp. 89-92, 96-99; Wooldridge, 2018, pp. 519-520). Defining $x_{t1} \equiv \widehat{FXI_t}$, the $1 \times K$ vector of explanatory variables including the constant and the set of regressors is denoted as

$$\boldsymbol{x_t} \equiv (1, x_{t1}, ..., x_{tk-1})$$

The $1 \times L$ vector ($L = K + M$) of all exogenous variables is then

$$\boldsymbol{z_t} \equiv (1, x_{t1}, ..., x_{tk-1}, z_{t1}, ..., z_{tm})$$

The exclusion restriction requires each instrument to be uncorrelated with the error term u_t. Hence,

$$E(\boldsymbol{z_t'} u_t) = \boldsymbol{0} \tag{4.3}$$

for some $1 \times L$ vector $\boldsymbol{z_t}$.

The second requirement is that

$$(a)\ rank\, E(\boldsymbol{z_t'z_t}) = L;\ (b)\ rank\, E(\boldsymbol{z_t'x_t}) = K \tag{4.4}$$

Part b is the full rank condition crucial for identification and requires $\boldsymbol{z_t}$ to be sufficiently linearly related to $\boldsymbol{x_t}$, so that rank $E(\boldsymbol{z_t'x_t})$ has full column rank. Sufficient linearity is achieved when at least one of the coefficients $\boldsymbol{c_m'}$ of the instruments in $\boldsymbol{Z_{tm}}$ is nonzero. This implies that $\boldsymbol{Z_{tm}}$ is partially correlated with FXI_t once the other explanatory variables have been netted out. The order condition $L \geq K$ is necessary for the full rank condition. It says that at least as many instruments as explanatory variables are needed to have identification. While Condition 4.4 can be tested, the fulfilment of Condition 4.3 is based on good reasoning because the error term u_t is not observable.

As mentioned earlier, the instruments used for the 2SLS estimation are measures of reserve adequacy that capture the SNB's precautionary savings motive. The literature distinguishes between three motives for accumulating foreign reserves: transaction, mercantilism, and precaution. Foreign reserve accumulation for transaction purposes aims at maintaining an adequate stock of foreign reserves to finance international transactions such as import bills. The mercantilist motive is based on the notion that foreign reserves help the central bank reduce exchange rate volatility and depreciate the exchange rate or maintain it favourably to promote exports and increase employment opportunities. Lastly, precautionary motives are based on the view that foreign reserves can provide self-insurance for a small open economy and maintain financial stability in case of sudden stops of capital flows, emergency currency liquidity assistance required by local banks or general financial volatility (Mondal, 2018, p. 10). Sudden capital outflows are less of a problem for Switzerland because the Swiss franc's safe-haven characteristics imply that capital usually flows into the country during global financial distress. However, the banking sector plays a vital role in the Swiss economy. The bailout of the Swiss bank UBS through the Swiss government and the SNB in 2008 demonstrated that Swiss banks are vulnerable to global financial crises, which poses a threat to domestic financial stability. Steiner (2013, pp. 211-212) notes that while problems in the banking sector occur independently of the level of central bank reserves, reserves might prevent a bank run as they lend credence to the government's insurance of private deposits. Further, precautionary reserves might be used to bail out banks without the need to increase sovereign debt, thereby preventing the transition from a banking to a sovereign debt crisis. Steiner (2013, pp. 211-212) also notes that foreign reserves might be necessary for a bailout if the bank's liabilities are denominated in foreign currency. This was the case for UBS, which had up to 54 billion in USD denominated illiquid assets financed by the SNB as part of its bailout (SFDF, 2008, p. 3).

Given the threat to domestic financial stability that Switzerland experienced during the global financial crisis and the SNB's need to contribute to the UBS bailout, it seems reasonable to assume that besides its mercantilist motive for reserve accumulation, the SNB also holds foreign reserves due to precautionary reasons. The two motives for reserve accumulation are expected to be independent of each other as both have completely different objectives. While the precautionary motive targets the financial sector's stability, the mercantilist motive aims to preserve the export sector's competitiveness. This implies that the precautionary reserve accumulation is expected to be correlated with FXI but uncorrelated with the exchange rate. Therefore, there exists good reason to assume that the exclusion restriction from Equation 4.3 is fulfilled when using measures of reserve adequacy as instrumental variables.

The literature has presented various metrics of reserve adequacy that capture the precautionary savings motive. These include, for instance, intermediate money (M2), the reserve-to-import ratio (NFA/Imports), M2/GDP and the reserve-to-intermediate money ratio (NFA/M2) (Adler et al., 2019, p. 6). The two metrics used as instruments for the 2SLS estimation of this thesis are the change in intermediate money and the reserves-to-intermediate money ratio. M2 captures the total size of domestic financial liabilities that could be readily converted to foreign currency (Obstfeld, Shambaugh, & Taylor, 2010, p. 57). The reserves-to-intermediate money ratio measures the potential domestic demand for foreign assets, especially relevant for financially developed countries with an open capital account (Arslan & Cantú García, 2019, p. 5). The selection of instrumental variables was restricted to those two metrics because the others did not pass the test required to fulfil Condition 4.4. The reader is referred to Appendix 1 for a detailed description of the variables and to Table 6.5 in Appendix 2 for the summary statistics of the variables.

While M2 is widely used in the literature as an instrument for FXI, particular caution is required in the case of Switzerland due to the primarily unsterilized nature of the SNB's FXIs. It has been shown in Chapter 2 that the unsterilized FXIs led to an increase in the monetary base (M0). M0 consists of cash in circulation, central bank reserves and other liabilities. Intermediate money (M2), in turn, consists of M0 plus overnight deposits and deposits with a maturity of fewer than two years (SNB, 2007, p. 11). In the case of unsterilized FXI, M2, which is used to capture the SNB's precautionary savings motive, is not independent of the mercantilist motive because the latter implies a change in M0, which is part of M2. This concern is supported by the fact that the correlation between M2 and M0 is 0.97. Hence, some additional steps had to be taken to ensure that the few variables which qualify as potential instruments are valid. To strengthen the exogeneity of M2, the change instead of the level was used, and the variable was lagged. Using this improved version of the M2 variable, the correlation between M2 and M0 is 0.04, giving good reason to believe that the exclusion restriction is fulfilled. The correlation of the improved M2 variable with FXI/GDP is -0.18. Hence, there is a potential threat to identification regarding the full rank condition because the instrument is only weakly correlated with FXI/GDP. However, the correlation of NFA/M2 with FXI/GDP is 0.61, suggesting that at least one of the two instruments causes sufficient variation in the endogenous variable. Since the instruments are used in combination, it can be reasonably assumed that the full rank condition is fulfilled. Lastly, the correlation of NFA/M2 with M0 is -0.07, suggesting that also for the second instrument, there is no threat to identification due to a breach of the exclusion restriction.

4.2.2 Results

Column 2 of Table 4.1 reports the results for the baseline 2SLS estimation for the FXI elasticity of the real bilateral exchange rate. The coefficient of FXI/GDP is -0.11 and statistically significant at the 5% level. Given that the relationship between the real bilateral exchange rate and FXI/GDP in Equation 4.2 is expressed in terms of log-level, the coefficient of FXI/GDP must be multiplied by 100 to get the correct interpretation (Wooldridge, 2018, p. 45). This means that a change of FXI by one unit, i.e. 1% of GDP, decreases the real bilateral exchange rate between the Swiss franc and the Euro by 11%. This result is significantly higher than the estimates found by Adler et al. (2019, pp. 2, 8-9) and Blanchard et al. (2015, p. 16), who estimate a positive FXI of 1% of GDP to depreciate the real bilateral exchange rate by 1.4-1.5% and 1.5% respectively.

Table 4.1: Baseline Estimation of the Second Stage

	Real Bilateral Exchange Rate	
	OLS	2SLS
	(1)	(2)
Constant	0.001	0.001
	(0.001)	(0.001)
FXI/GDP	−0.02	-0.11^{**}
	(0.02)	(0.04)
VSTOXX	−0.0001	−0.0001
	(0.0005)	(0.001)
Energy	−0.03	−0.05
	(0.03)	(0.03)
Metal	0.08^{***}	0.09^{***}
	(0.03)	(0.03)
Food	−0.04	−0.06
	(0.06)	(0.05)
Interest Differential	-0.06^{***}	-0.06^{***}
	(0.01)	(0.02)
Trade Balance	−3.61	−3.98
	(3.07)	(2.96)
Weak Instruments		29.88^{***}
Wu-Hausman		18.00^{***}
Sargan		1.55
F-Statistic	10.38^{***}	15.62^{***}
N	132	132
R^2	0.37	0.20
Adjusted R^2	0.33	0.16

*Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.* Heteroskedasticity- and serial correlation robust standard errors in parantheses. The F-Statistic of the 2SLS refers to the first stage.

Several reasons might explain the higher impact of FXI found with the 2SLS estimation compared to the literature. First, a distinction must be made between sterilized and unsterilized FXIs. It has been demonstrated in Chapter 2 that most of the SNB's FXIs during the period 2009-2019 were unsterilized. While there is a consensus in the literature that unsterilized FXIs directly influence the real exchange rate, Iwata and Wu (2012, p. 430) also showed that an unsterilized FXI has a greater impact on the exchange rate than a sterilized one. Given that the literature of reference focuses on the effect of sterilized interventions and large panels of countries (between 35 and 50), it seems reasonable that the effect of the mostly unsterilized FXIs conducted by the SNB had a larger impact on the real exchange rate than was found in those studies. Second, the studies of reference focus on the exchange rate between the local currency and the USD, not the EUR, and few of these currencies exhibit safe-haven characteristics comparable to the Swiss franc. This implies that the monetary policy setting for the countries used in the literature is possibly very different, making the estimates difficult to compare yet explaining part of the deviation. Third, the estimations in the literature only cover the period up to 2013. Having in mind the finding by Steiner (2017, p. 126) that foreign currency growth and hence, FXIs, unfold their largest effect after three years, the different results could be partly explained by the fact that previous studies were not able to capture the effect of the different economic setting that prevailed after the global financial crisis. The effect of FXIs on the exchange rate could have increased after the global financial crisis, for example, due to the higher credibility of this monetary policy tool given the large-scale use after 2009. However, the studies examining the period up to 2013 might not have been able to capture this due to the lagged effect of FXIs. Fourth, despite having the required F-statistic for a valid instrument, it might be that the two instruments used were not strong enough, leading to an overestimation of the effect. This assumption is supported by the low correlation of the improved M2 variable with FXI/GDP. Lastly, given the peculiarities of the Swiss franc and the SNB's monetary policy, i.e. the unsterilized nature of its FXIs, it might also be the case that the widely used measures of reserve adequacy as instruments for FXI are not suitable for the particular case of Switzerland.

Column 1 of Table 4.1 displays the results obtained when estimating the same model with OLS. The coefficient of FXI/GDP is -0.02 and has the expected sign. It is much smaller than the 2SLS estimate but not statistically significant. In this case, FXI and the real bilateral exchange rate are determined simultaneously, implying that FXI is endogenous (Wooldridge, 2010, p. 51). Multiplying the coefficient by 100 due to the log-level specification of Equation 4.2 implies that a positive FXI by 1% percentage point of GDP depreciates the Swiss franc by 2%. This is considerably closer to the estimate found by Blanchard et al. (2015) and Adler et al. (2019) than the coefficient obtained with the 2SLS estimation. However, in addition to the absence of statistical significance of the OLS estimate, the diagnostic tests of the 2SLS estimation give good reason to trust the 2SLS rather than the OLS results.

The first test conducted as part of the 2SLS estimation was the weak instruments test. This test checks whether the full rank condition from Equation 4.4 is fulfilled by testing whether the instrumental variables are sufficiently correlated with the endogenous explanatory variable.

Given the null hypothesis that all instruments are weak, rejecting the null hypothesis suggests that at least one of the instrumental variables is strong, i.e. has a coefficient that is not zero. The result is reported in column 2 of Table 4.1. The statistic of the weak instrument test is 29.88 and statistically significant at the 1% level, implying that at least one of the two instruments used for the 2SLS estimation is strong. The strength of the instruments was further examined by looking at the first-stage F-statistic, which is reported in column 2 of Table 4.1. Stock and Yogo (2005, p. 106) suggest that an instrument can be considered strong if it has a first-stage F-statistic larger than 10. The first-stage F-statistic is 15.62 and is statistically significant at the 1% level, suggesting that M2 and NFA/M2 are strong enough instruments. However, given that the estimation differs considerably from the literature, the question is whether an F-statistic of 15.62 is large enough for the case at hand. Finding stronger instruments fulfilling the exclusion and full rank conditions is complex and left as a possible future area of research. For this thesis, instruments fulfilling the requirements commonly taught at master level econometrics courses shall be deemed sufficient, accepting the disadvantage that the estimation might not be as close to the actual effect as it could be.

The second diagnostic reported in Table 4.1 is the statistic of the Wu-Hausman test of endogeneity. The test compares the OLS and the 2SLS estimates and determines whether the differences are statistically significant. If all explanatory variables are exogenous, both OLS and 2SLS are consistent, and the OLS estimator is more efficient. In contrast, if one or more of the explanatory variables are endogenous, the OLS estimator is inconsistent, and the 2SLS estimator should be preferred. Hence, finding a statistically significant test output implies that the explanatory variable of interest is endogenous (Wooldridge, 2018, p. 515). The Wu-Hausman statistic for the 2SLS estimation is 18 and statistically significant at the 1% level. This supports the conjecture that the FXI/GDP variable is endogenous. Despite the OLS results being closer to the estimates found in the literature, they cannot be trusted because they ignore the inherent endogeneity problem.

The last test conducted was the Sargan test of overidentification, which helps to identify whether a model is misspecified. When a regression is overidentified, i.e. has more instrumental variables than coefficients to estimate, the instrumental variables can provide conflicting information about the coefficients. The test points towards model misspecification if the null hypothesis is rejected. Given the test statistic of 1.55 and the absence of statistical significance, one can conclude that the model is not misspecified. Overall, the diagnostic tests support the preference of 2SLS over OLS, the choice of instrumental variables, the model specification, and the assumption that the variable FXI/GDP is endogenous when used without instruments. However, as part of future research, the estimation could be improved by finding stronger instruments.

4.3 Robustness Checks

The robustness of the above results was examined in different ways. In a first step, it was tested whether the results are robust to the inclusion of more control variables and the use of the nominal instead of the real bilateral exchange rate. The second and third steps tested whether using alternative proxies for FXI and dropping or exchanging specific instruments gives the same results. Given the difference in the results from those in the literature, the robustness checks are essential and explained in detail.

4.3.1 Dependent and Independent Variables

Table 6.6 in Appendix 2 reports the results for the 2SLS estimation using the real bilateral exchange rate and the results for the 2SLS estimation using the nominal bilateral exchange rate for both the normal and the expanded set of controls. The results found in the original specification seem to be robust to any of the three variations. The coefficient of the model with the real bilateral exchange rate and the expanded set of controls is -0.12 and statistically significant at the 1% level. This is marginally larger than the results found with the normal set of controls. However, it supports the view that the FXI/GDP coefficient obtained with the 2SLS estimation has the correct magnitude. The fact that the test diagnostics of the estimations using the normal and the expanded set of controls have a similar magnitude and the same statistical significance further supports the robustness of the results.

The findings also seem robust to replacing the real bilateral exchange rate with the nominal bilateral exchange rate using both the normal and the expanded set of controls. Both coefficients are -0.11, yet while the result using the expanded set of controls is statistically significant at the 1% level, as was the case for the original specification, the coefficient using the normal set of controls is only significant at the 5% level. With a value of 11, the F-statistics of both cases are lower than those obtained for the real bilateral exchange rate, suggesting that the instruments are not as successful in generating an exogenous variation of the FXI/GDP variable. The rest of the diagnostic tests yield similar results to those obtained using the real bilateral exchange rate in terms of magnitude and statistical significance.

4.3.2 Proxy

The difficulties of finding a good proxy for FXI and the proxy used in this thesis have been pointed out in Chapter 4.2.1. However, it is worth stressing again the advantage the proxy constructed by Adler et al. (2021) has over previous proxies based on the central bank's foreign exchange reserves. The conventional proxies for FXI are often not adjusted for valuation changes and investment income flows and are distorted by the central bank's exchange of local and foreign currency assets (Adler et al., 2021, pp. 3, 5). In the absence of these adjustments, a change of the proxy might, for instance, reflect changes in the central bank's foreign currency reserves caused by varying market prices or exchange rate movements, or it might reflect the return on foreign currency investments. Those changes do affect the foreign currency position of the central bank. However, they are not the result of an active FXI. Changes in the central bank's foreign currency position can also be caused by portfolio management operations that reallocate between the reserve and non-reserve assets or by operations that the central bank conducts on behalf of other domestic entities such as the government. As these changes are not the result of an FXI, they dilute the actual level of FXIs conducted by the SNB. Adler et al. (2021, pp. 6-7, 15-16) address this shortcoming by constructing a proxy which includes spot and derivative transactions that are adjusted for valuation changes, investment income, other foreign currency assets and liabilities vis-à-vis non-residents as well as foreign currency assets and liabilities vis-à-vis residents. They test their proxy against published FXI data and other proxies for FXI and find that their proxy clearly outperforms other FXI proxies. They also find that the advantage of their proxy over the others is even more substantial when focusing on the period 2010-2019 only, as compared to the period 2000-2019 in the original estimation.

Given their findings and the recency of their study, the FXI proxy constructed by Adler et al. (2021) seems the best one available at the time of writing this thesis. However, for completeness, robustness checks were conducted using two alternative proxies. The first proxy uses the sight deposit position of banks on the SNB's balance sheet as an approximation for the SNB's FXIs. In contrast to other central banks, the SNB allows banks with foreign domicile to participate in its repo system, implying that even banks that are not resident or do not maintain a branch in Switzerland can hold a sight deposit account at the SNB. The link between sight deposits and FXI interventions results from the safe-haven characteristics of the Swiss franc. During times of global turmoil, parties not resident in Switzerland move their assets to a bank registered in Switzerland or to their foreign branch's office in Switzerland to acquire CHF denominated assets. Either way, the banks directly deposit any funds that flow into Switzerland in their sight deposit accounts at the SNB (Auer, 2015, pp. 49-52). The increased demand for the Swiss franc leads to an appreciation of the currency, forcing the SNB to intervene in the foreign exchange market. Under the assumption that the SNB intervenes in the FX market by the number of funds that flow into Switzerland, the sight deposits of banks on the SNB's balance sheet serve as a proxy for the FXIs conducted by the SNB. However, as the sight deposit position is not adjusted for valuation changes, the proxy suffers from the same shortcomings as the other conventional proxies. The second proxy uses the foreign currency investment position on the SNB's balance sheet to approximate the SNB's FXIs. This is the typically used proxy, and hence, the drawbacks described above apply. The two alternative proxies were also divided by GDP to obtain an estimate comparable with the original specification in which FXI/GDP was used as a proxy.

Table 6.7 in Appendix 2 reports the results obtained using the alternative proxies with the real bilateral exchange rate as the dependent variable and the normal set of controls. The first column displays the results received when sight deposits are used as a proxy for FXI, while the second column reports the results when FXI is proxied by foreign currency investments. The coefficient of sight deposits/GDP is -0.05 and statistically significant at the 10% level. The significance level is unsatisfactory, and the test diagnostics also advocate against using this model.

While there is statistically significant evidence at the 1% level that at least one of the instruments is strong, the F-statistic of the first stage is 3.83 and does not pass the required threshold of 10 to have strong enough instruments. Further, the Wu-Hausman test result suggests that endogeneity is present, and hence, 2SLS instead of OLS should be used. However, the Sargan test statistic is statistically significant at the 5% level, implying that the model is misspecified. In conclusion, the results found in the original specification are not robust to the use of sight deposits of banks as an alternative proxy. Nevertheless, given the results of the diagnostic tests and the advantages of the FXI/GDP proxy discussed above, these results do not speak against the validity of the findings obtained in the original estimation.

When foreign currency investments are used as a proxy for FXI, the coefficient of interest is -0.13 and statistically significant at the 1% level. While this is reasonably close to the coefficient of -0.11 found in the original specification, there is weak evidence that the model might be misspecified because the Sargan test statistic is statistically significant at the 10% level. The other diagnostic checks all yield favourable results, but with a value of 13.48, the first-stage F-statistic is slightly lower than in the original specification. This implies that the instruments seem weaker in this setting as they cause less exogenous variation in the endogenous variable. Overall, using foreign currency investments as a proxy for FXI supports the results found in the original estimation. The slightly worse results of the diagnostic tests support the preference of the FXI proxy constructed by Adler et al. (2021) over any other, less sophisticated proxy.

4.3.3 Instruments

The robustness of the original findings concerning the instruments was tested in different ways. In a first step, NFA/M2 was replaced by NFA/GDP to check whether the results were driven by the twofold use of M2 as an instrument. In a second step, each instrument of the original specification was dropped at a time to check whether a specific instrument drove the results. Lastly, the original instruments were replaced completely to check whether other instruments could have been used.

Column 1 in Table 4.2 displays the results that are obtained when the instrument NFA/M2 is replaced with NFA/GDP. It is not a problem to have high collinearity between instruments if they are uncorrelated with the error term (Wooldridge, 2018, p. 476). However, it is still interesting to know whether the results are driven by the twofold use of M2 as an instrumental variable. When using NFA/GDP and M2 as instruments, the coefficient of FXI/GDP is -0.1 and statistically significant at the 5% level. Hence, the magnitude of the coefficient is almost the same as when NFA/M2 and M2 were used as instruments. However, the statistical significance is slightly lower. The diagnostic checks also yield very close results to the original specification. Still, given the first-stage F-statistic of 12.39, this combination of instruments seems to be slightly weaker than the combination used in the baseline specification. Overall, the findings confirm the robustness of the baseline results, but they also suggest that the result is slightly driven by using M2 as an instrumental variable.

Table 4.2: Robustness Checks of the Instruments, Second Stage

	Real Exchange Rate		
	NFA/GDP, M2	M2	NFA/M2
	(1)	(2)	(3)
Constant	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)
FXI/GDP	-0.10^{**}	-0.06	-0.14^{*}
	(0.04)	(0.05)	(0.07)
VSTOXX	-0.0001	-0.0001	-0.0001
	(0.001)	(0.0005)	(0.001)
Energy	-0.05	-0.04	-0.06
	(0.03)	(0.03)	(0.04)
Metal	0.09^{***}	0.08^{***}	0.09^{**}
	(0.03)	(0.03)	(0.04)
Food	-0.06	-0.05	-0.06
	(0.05)	(0.05)	(0.06)
Interest Differential	-0.06^{***}	-0.06^{***}	-0.07^{***}
	(0.02)	(0.01)	(0.02)
Trade Balance	-3.96	-3.79	-4.09
	(2.92)	(2.73)	(3.35)
Weak Instruments	26.03^{***}	17.96^{***}	32.82^{***}
Wu-Hausman	13.54^{***}	1.08	16.71^{***}
Sargan	1.35		
F-Statistic	12.39^{***}	19.47^{***}	4.91^{**}
N	132	132	132
R^2	0.22	0.33	0.08
Adjusted R^2	0.18	0.29	0.03

*Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.* Heteroskedasticity- and serial correlation robust standard errors in parantheses. The F-statistic refers to the first stage of the regression. Column names refer to the instruments used.

Column 2 in Table 4.2 displays the results obtained when NFA/M2 is dropped from the baseline specification, leaving M2 as the only instrument. The coefficient of -0.06 is not statistically significant, but the first-stage F-statistic is 19.47 and statistically significant at the 1% level. This suggests that the instrument is quite strong but cannot generate enough exogenous variation in FXI/GDP on its own. When NFA/M2 is the only instrument, the coefficient is -0.14 and statistically significant at the 10% level. While the magnitude is close to the one obtained in the baseline specification, the statistical significance is weak. Given the first-stage F-statistic of 4.91, the instrument does not seem strong enough to be used independently. The Sargan test cannot be conducted when only one instrumental variable is used, leaving an open question regarding the possible misspecification of the model. The conclusion from the estimations shown in columns 2 and 3 of Table 4.2 is that the results are not robust to dropping one of the instruments. While the joint instrument strength seems to be driven by M2, the coefficient appears to be determined mainly by NFA/M2.

Other instruments, which were mentioned in the literature as metrics of reserve adequacy, have been tested. These include the reserve-to-import ratio (NFA/imports), M2/GDP, the current-account-to-GDP ratio, and the short-term debt-to-GDP ratio. However, as no combination of them yielded a first-stage F-statistic larger than 10, they were not strong enough instruments to deliver reliable results for the baseline estimation. Therefore, it was tested whether they could be used as instruments for the alternative proxies presented above. For sight deposits/GDP, the answer is negative. The results were either statistically insignificant, the instruments were too weak, or the model seemed to be misspecified. However, for the foreign currency investments/GDP proxy, similar results to the baseline specification were obtained, although with different instrumental variables. The results can be found in Table 4.3. For the case where NFA/M2 and NFA/GDP and for the case where NFA/GDP and M2/GDP were used as instruments, the coefficient of interest is -0.14 and statistically significant at the 1% level. The diagnostic checks all support using these models, but with first-stage F-statistics of 12.72 and 11.07, the instruments are weaker than the baseline specification. For the case where NFA/GDP and NFA/imports were used as instrumental variables, the coefficient is -0.13 and statistically significant at the 1% level, while the first-stage F-statistic is 11.71. The conclusion drawn from these estimations is that the results found in the baseline specification are robust to using a different combination of FXI proxies and instrumental variables. While these robustness checks find coefficients for FXI that are statistically significant at the same level but have a slightly higher magnitude, the results from the baseline specification are still to be preferred given the higher first-stage F-statistic, i.e. the stronger instruments. Regarding the earlier mentioned possible problem of too weak instruments, this suggests that it is not the instruments used in the baseline specification but the fact that measures of reserve adequacy might not suit the particular case of Switzerland, which could partly explain the deviation of the results from those in the literature.

Table 4.3: Robustness Checks with Alternative Proxies and Instruments, Second Stage

	Real Exchange Rate		
	NFA/M2, NFA/GDP	NFA/GDP, NFA/IM	NFA/GDP, M2/GDP
	(1)	(2)	(3)
Constant	0.004**	0.004**	0.004**
	(0.002)	(0.002)	(0.002)
FCI/GDP	−0.14***	−0.13***	−0.14***
	(0.04)	(0.04)	(0.04)
VSTOXX	0.0004	0.0004	0.0004
	(0.001)	(0.001)	(0.001)
Energy	−0.03	−0.03	−0.03
	(0.03)	(0.02)	(0.02)
Metal	0.08**	0.08**	0.08**
	(0.03)	(0.03)	(0.03)
Food	−0.05	−0.05	−0.05
	(0.06)	(0.06)	(0.06)
Interest Differential	−0.06***	−0.06***	−0.06***
	(0.01)	(0.01)	(0.01)
Trade Balance	−3.32	−3.34	−3.33
	(2.59)	(2.60)	(2.59)
Weak Instruments	32.08***	28.88***	29.99***
Wu-Hausman	6.76**	4.15**	5.81**
Sargan	1.55	0.12	2.51
F-Statistic	12.72***	11.71***	11.07***
N	132	132	132
R^2	0.36	0.38	0.36
Adjusted R^2	0.32	0.34	0.33

*Notes: * p < 0.1, ** p < 0.05, *** p < 0.01.* Heteroskedasticity- and serial correlation robust standard errors in parantheses. F-statistic refers to the first stage of regression, column names to instruments used.

Overall, the robustness checks demonstrated that the results are quite robust to using different dependent and independent variables, alternative proxies, and a different combination of FXI proxies and instruments. However, there is a slight dependence on M2 and NFA/M2 as instrumental variables. Three further shortcomings are worth noting. First, the 2SLS estimation is heavily dependent on finding good instruments. While it can be tested whether the instrumental variables are sufficiently correlated with the endogenous variable, it cannot be observed whether the instrumental variables are uncorrelated with the error term. Hence, this assumption is based on good reasoning only. The instruments pass the required first-stage F-statistic of 10, but the significant deviation of the results from those in the literature suggests that they might still be too weak for this particular case. The robustness checks showed that the deviation is likely not driven by the specific set of instruments but caused by the fact that using measures of reserve adequacy as an instrument for FXI might not be suitable for the case of Switzerland. It is left as a future avenue of research to find a type of FXI instrument that better suits Swiss particularities. Second, due to the lack of FXI data, the estimation relies on using a proxy variable. While the proxy constructed by Adler et al. (2021) seems to be the best option available at the time of writing this thesis, there is still the risk that this variable includes changes in the SNB's reserve position that were not the result of an active FXI. In 2020, the SNB started to publish monthly FXI data. Given that the dataset by Adler et al. (2021) is updated periodically, future research could test how close their proxy is to the actual data. Lastly, the 2SLS estimation might not have been able to capture all the circularity inherent in monetary policy. While the 2SLS estimation addressed short-term circularity arising from the simultaneity of FXI and exchange rate movements, the longer-term circularity was not considered. The SNB monitors the market and bases its monetary policy decisions on historical market data, which uses relationships involving past expectations and beliefs. Since these change over time, generalizations of the SNB's monetary policy effects are unreliable. While the SNB monitors the market to determine its monetary policy, the market observes the SNB to assess how it should respond to the SNB's monetary policy. This creates a circularity problem where market data may fail to recognize certain risks because the market expects the SNB to respond. Ignoring this circularity implies that the measured effect does possibly not represent the real effect of monetary policy, or the impact it had at a certain point in time cannot be generalized to the whole period of interest.

5 Assessment of the Prevented Export Sector Damage

In the previous two chapters, the real exchange rate elasticity of Swiss exports and the FXI elasticity of the real exchange rate between the Swiss franc and the euro were estimated. In the next step, those estimates are put together to calculate the damage which would have occurred to the Swiss export sector in the absence of the SNB's FXIs. This benefit quantification will be compared to the costs composed of the amount of FXI and any materialization of the risks mentioned in Chapter 2. Comparing the benefits of the SNB's FXIs with the costs will help assess from an export sector perspective whether it is justified to take the direct and indirect risks that arise from intervening in the FX market.

5.1 Calculation of the Prevented Export Sector Damage

Based on the numbers revealed in its annual reports, the SNB purchased foreign currencies amounting to CHF 639.5 billion from 2009 to 2019. According to data from the SECO, the total real Swiss GDP during that period was CHF 7'312.214 billion. Hence, the SNB's FXIs during that period amounted to

$$639.5/7'312.214 = 0.0875 = 8.75\%$$

of GDP. As part of the 2SLS estimation, a foreign exchange intervention of 1% of GDP was found to decrease the real bilateral exchange rate by 11%. Therefore, over the period 2009-2019, the foreign exchange interventions of 8.75% of GDP decreased the real bilateral exchange rate by a cumulative $8.75 * 11\% = 96.25\%$. In the POLS estimation, a 10% depreciation of the real bilateral exchange rate was found to increase Switzerland's exports by 2.4%. Hence, a devaluation of the real bilateral exchange rate by a cumulative 96.25% during the period 2009-2019 increased Switzerland's exports by $96.25 * 0.24\% = 23.1\%$. According to data from the SFCA, Switzerland's total exports from 2009 to 2019 amounted to CHF 2'997.7 billion. If the SNB had not intervened in the FX market by that 8.75% of GDP during the period 2009-2019, Swiss exports would have been

$$2'997.7/1.231 = 2'435.2$$

billion CHF. To put it differently, if the SNB had not intervened by 8.75% of GDP during the said period, this would have cost the Swiss export sector CHF $2'997.7-$ CHF $2'435.2 =$ CHF 562.5 billion. These prevented costs quantify the benefits of the SNB's FXIs. Putting this into context, the SNB's FXIs exceeded the prevented export sector damage by CHF $639.5-$ CHF $562.5 =$ CHF 77 billion. Table 5.1 summarizes the previously calculated results. Based on this simple cost-benefit comparison, the preliminary conclusion is that the costs of the SNB's FXIs were higher than the benefits. However, this conclusion does not consider the costs arising from the materialized risks explained in Chapter 2 and any other potential benefits of FXI. The following subchapter will take a broader perspective on this cost-benefit analysis.

Table 5.1: Benefit Calculation of FXI

Variable During Period 2009-2019	Amount / Share
FXIs	CHF 639.5 billion
Real GDP	CHF 7'312.214 billion
FXI as Percentage of GDP	639.5/7'312.214 = 8.75%
Decrease of Real Exchange Rate by FXIs	8.75 * 11% = 96.25%
Export Increase due to FXIs	96.25 * 0.24% = 23.1%
Exports in Absence of FXIs	2'997.7/1.231 = CHF 2'435.2 billion
Benefit of FXIs (Prevented Export Sector Damage)	2'997.7 – 2'435.2 = CHF 562.5 billion
Difference between Costs and Benefits	639.5 – 562.5 = CHF 77 billion

Given that the estimate of the FXI elasticity of the real exchange rate deviated quite strongly from the estimates in the literature, it is worth checking whether the result would be different if the estimates from the literature were used. If the 1.5% FXI elasticity of the real exchange rate estimated by Blanchard et al. (2015) and Adler et al. (2019) was used instead of the 11% calculated in Chapter 4, the conclusion would still be that the costs of the SNB's FXIs were higher than their immediate benefit. The exact calculation can be found in Table 6.8 of Appendix 2. In this scenario, the benefits arising from the prevented export sector damage would have amounted to CHF 91.55 billion. Comparing this number with the costs of FXI amounting to CHF 639.5 billion would lead to the conclusion that the costs were CHF 547.95 billion higher than the benefits. Hence, while the difference between the costs and benefits would be significantly larger if the estimates from the literature were used, the overall conclusion that the costs were higher than the benefits remains the same.

If the same thought experiment is done using the literature estimate of a 4.2% real exchange rate elasticity of Swiss exports estimated by Thorbecke and Kato (2018) instead of the 2.4% estimated in Chapter 3, the conclusion would be that the benefits of FXI were higher than their costs. The exact calculation can be found in Table 6.9 of Appendix 2. In this case, the benefits of FXI in terms of prevented export sector damage would amount to CHF 862.96 billion. Comparing the benefits with the costs of FXI of CHF 639.5 billion would lead to the conclusion that the benefits of FXI were CHF 223.46 billion higher than the costs. Therefore, the cost-benefit comparison seems more sensitive to estimating the real exchange rate elasticity of Swiss exports than the FXI elasticity of the real exchange rate. This suggests that the substantial deviation of the latter from the literature should not affect this preliminary conclusion of the cost-benefit analysis.

The above calculations are subject to the data availability problem discussed in previous chapters. The FXI data used as the basis for the calculation was taken from the SNB's annual reports for the years 2009-2019. While this seems the most reliable data available, it is subject to the limitation that the SNB might not have revealed the total amount of FXI it conducted. The robustness of the estimates has been demonstrated in the previous two chapters, and the benefits of CHF 562.5 billion in terms of prevented export sector damage should therefore be considered the best estimate available. As pointed out in the introduction, this way of estimation is inferior to calculating the prevented damage using a counterfactual. However, it is the best option available that suits the scope of this thesis.

5.2 Cost-Benefit Analysis of the SNB's Foreign Exchange Interventions

The preliminary conclusion of the above cost-benefit analysis was that the costs of the SNB's FXIs were CHF 77 billion higher than their benefits. The result was labelled as a preliminary conclusion because it was solely based on comparing the amount of FXI with the prevented export sector damage. For a complete assessment, the potential risks of FXI mentioned in Chapter 2.5 and potential benefits implied by the prevented export sector damage must also be considered.

Looking at the cost side, the question is whether there were additional costs to the CHF 639.5 billion of FXI during the period of interest. The most significant potential risk mentioned in Chapter 2.5 is the inflationary pressure that could arise if the FXIs are not sterilized. Figure 2.1 in Chapter 2.3, which shows the development of Swiss inflation during the period 2004-2019, suggests that inflation was strongest during 2008-2009, but this was partly before the SNB started its large-scale FXIs. Hence, inflationary pressures do not seem to have been an issue during the period of interest. However, they could suddenly get strong, e.g. due to the global recovery after the Covid-19 pandemic. If this goes out of hand, the SNB risks losing the credibility needed to successfully stabilize inflation and the exchange rate. The second drawback of FXI is its potential risk to domestic financial stability. The Swiss financial stability was considerably threatened in 2008, which resulted in the need for the Swiss government and the SNB to bail out UBS. Given that this happened before the SNB started its massive FXIs, the incident should be considered a result of the global financial crisis and not of the SNB's FXIs. To the best of the author's knowledge, no other major threat to domestic financial stability occurred during the period of interest. Hence, this risk does also not seem to have materialized. The third risk that emerges from FXIs is the valuation losses due to exchange rate volatility. Based on data that the SNB revealed in its annual reports for 2009-2019, the SNB made a net profit on its currency reserves of CHF 137.7 billion. In 2010 and 2018, the SNB experienced a loss on its foreign currency reserves, which was offset by the profit gained in the other years. Thus, for the period of interest, the SNB's foreign currency position on its balance sheet was not a potential cost but rather a benefit. However, it would be naive to conclude from this experience that valuation losses cannot occur in the future, which means that this is still a potential risk that has to be considered going forward. The last type of cost the Swiss economy could have suffered due to the SNB's FXIs are punitive measures that the US took when it declared Switzerland a currency manipulator. To the best of the author's knowledge, no such actions were taken against Switzerland, and the country was removed from the list when the Biden administration came to power. Hence, overall, the potential direct and indirect risks of FXI do not seem to have materialized during the period 2009-2019, which implies that the costs of the SNB's FXIs amounted to CHF 639.5 billion. If one nets this amount with the profit the SNB made on its foreign currency reserve position during that period, the remaining costs are CHF 501.8 billion.

The most significant benefit which the Swiss economy experienced through the SNB's FXIs was the prevention of CHF 562.5 billion damage which the Swiss export sector would have suffered from through the appreciation of the Swiss franc. The higher GDP, which resulted from the higher exports compared to a scenario with a stronger Swiss franc, can be considered a direct effect of this damage prevention. Eventually, the whole economy benefited from the prosperity of the Swiss export sector, for example, through taxes and transfers. The SNB's FXIs also had an indirect positive effect. Preventing the Swiss franc from becoming even stronger likely safeguarded foreign demand and domestic employment opportunities. If Swiss exporters had to shut down their business because the demand for their products was too low due to the strong Swiss franc, jobs would have been lost. The structural change that would have happened to the economy was unlikely to be quickly reverted once the Swiss franc became weaker and should thus be seen as a long-term consequence. This suggests that the SNB's FXIs potentially helped secure job opportunities and safeguarded the structure of the Swiss economy. While quantifying this benefit would be a master thesis on its own, it is an essential factor to consider when evaluating the potential benefits and costs of FXI. Going one step further, a correctly valued Swiss franc most likely safeguarded jobs and encouraged investments that potentially created even more jobs, ensuring sustained economic growth. Eventually, the job creation and retention might have acted as a multiplier on the economic benefits of FXIs through higher tax income and lower unemployment benefits.

In conclusion, the costs of the SNB's FXIs conducted during the period 2009-2019 amounted to CHF 639.5 billion and were CHF 77 billion higher than the benefit of CHF 562.5 billion. The risks of FXI do not seem to have resulted in additional costs, and net of the valuation gains that the SNB made on its foreign reserve holdings, the costs were lower than their benefit. The most important additional benefits of FXI are economic structure and job preservation, and job creation. While these benefits are hard to quantify, they are potentially significant due to their multiplier effects. Giving these benefits a substantial weight in the evaluation leads to the conclusion that the benefits of FXI have outweighed the costs during the period of interest. However, this could be partly attributed to mere luck, as the SNB cannot influence the global economic conditions and has only limited options to control the valuation gains or losses it incurs on its reserve holdings. Going forward, the risks of FXIs should be assessed continuously as the economic environment can change quickly. Measures should be taken to minimize the risks of FXIs mentioned in Chapter 2.5, such as the diversification of the SNB's reserve assets. It is worth noting that the above cost-benefit analysis focused on the Swiss export sector only. To get a more comprehensive picture of the SNB's FXIs' implications, a desirable next step would be to include the import side in the cost-benefit analysis.

6 Conclusion

In the context of the US accusation of Switzerland being a currency manipulator, this thesis aimed to conduct a cost-benefit analysis of the SNB's FXIs, focusing on the Swiss export sector. To that end, the damage that would have occurred to the Swiss export sector from 2009 to 2019 without the SNB's FXIs was calculated. A POLS estimation was used to estimate the exchange rate elasticity of exports, and a 2SLS estimation helped quantify the FXI elasticity of the CHF/EUR exchange rate.

The POLS estimation found that a 10% depreciation of the real bilateral exchange rate with its trade partners increases Switzerland's exports by 2.4%. Using the 2SLS estimation, it was established that a foreign exchange intervention by 1% of GDP decreases the real bilateral CHF/EUR exchange rate by 11%. Based on the CHF 639.5 billion FXIs that the SNB conducted during the period 2009-2019, the results of the two estimations helped to establish that the benefits of preventing export sector damage amounted to CHF 562.5 billion. This implies that the costs of CHF 639.5 billion of the SNB's FXIs were CHF 77 billion higher than the benefits. Taking a broader perspective, the direct and indirect risks of FXI do not seem to have resulted in additional costs, and net of the valuation gains that the SNB made on its foreign reserve holdings, the costs were lower than their benefit. Further, the indirect benefits of FXI, namely the preservation of the Swiss economic structure and jobs and the potential job creation, can have large multiplier effects. Given the strong domestic demands for the protection of the Swiss export sector and the importance of economic considerations in Swiss policy-making, the job preservation and valuation gains could serve the SNB as strong arguments to justify its monetary policy decisions. Hence, giving these benefits a substantial weight in the evaluation leads to the conclusion that the benefits of FXI have outweighed the costs during the period of interest.

The findings of the POLS and 2SLS estimations proved robust to a range of alternative model specifications. Nevertheless, they suffer from various limitations, such as the difficulty of finding good proxy and instrumental variables for FXI. While the proxy for FXI constructed by Adler et al. (2021) seems to be the best option available at the time of writing this thesis, it is nevertheless inferior to using actual data of the SNB's FXIs. The significant difference between the 2SLS estimate and the estimates found in the literature further suggests that there are potential problems with using measures of reserve adequacy as instrumental variables of FXI in the particular case of Switzerland. Moreover, the method used to investigate the question of interest is only considered the second-best option available. The preferred one is the computation of counterfactual exports without any FXIs. Lastly, the cost-benefit analysis and the resulting conclusions only focus on the export sector. While the strong export dependence of Switzerland justifies this focus, a comprehensive cost-benefit analysis would also look at the import sector due to the effect of exchange rate movements on import prices. An appreciating Swiss franc makes Swiss imports cheaper, implying that the lower import prices could partially offset the Swiss export sector's loss when the Swiss franc becomes stronger.

The external relevance of the above findings is twofold. On the one hand, the US accused several other countries of being currency manipulators or put them on the currency manipulator watchlist. While their motive for FXI might be entirely different from the one of Switzerland, they might also be interested in the effect their FXIs have on the exchange rate, the impact that the exchange rate has on exports or the potential costs and benefits of FXIs. On the other hand, the findings can help nurture the discussion about the benefits and drawbacks of reserve accumulation in the context of the continuous increase of the central banks' reserve holdings since the demise of the Bretton Wood system (Steiner, 2013, p. 208).

There are four possible avenues of future research. First, the research could focus on conducting a cost-benefit analysis of FXI that includes the import sector to get a more comprehensive view of the costs and benefits of FXI. Going beyond that, the analysis could also include the costs that would arise from a failure to stabilize prices. Second, calculating the counterfactual volume of Swiss exports in the absence of any FXI would help verify the method used for this thesis and potentially deliver more accurate results. Third, given the particularities of Switzerland, future research could focus on finding instrumental variables for FXI that are stronger than the measures of reserve adequacy frequently used in the literature and for this thesis. Lastly, given that the SNB restarted to publish its FXI data in 2020, the proxy of FXI constructed by Adler et al. (2021) could be evaluated against the real data and possibly be improved.

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Appendix

Appendix 1

Variables List and Definitions

Variable Name	Definition	Source
Ordinary Least Squares		
Net foreign assets	Monthly net foreign assets (Foreign Currency Reserves + IMF Reserve Position + SDR + Gold) in million CHF was transformed to billion CHF.	SNB
Net domestic assets	Monthly net domestic assets (claims from CHF repo transactions + claims from US repo transactions + balances from swap transactions against CHF + secured loans + amounts due from domestic correspondents + CHF securities + loan to stabilization fund + other assets) in million CHF were transformed to billion CHF.	SNB
Pooled Ordinary Least Squares		
Real exports	Quarterly exports in CHF converted to million CHF and deflated using the Swiss franc export unit value index. The estimation is conducted for total exports, exports of capital goods, consumption goods, pharmaceuticals, non-pharmaceuticals and watches respectively.	SFCA
Real exchange rate	Quarterly bilateral real exchange rate between each importing country and Switzerland (LC/CHF) (increase = depreciation). The real exchange rate was computed using the end of period nominal bilateral exchange rate between each export partner and the euro area (LC/EUR) as well as the CPI of the export partner and Switzerland.	IFS
Real GDP	Quarterly seasonally adjusted real GDP of Switzerland's export partners in millions of the export partner's currency, converted to million CHF using the previously constructed nominal bilateral exchange rate between Switzerland and each export partner (LC/CHF). For China, India, Russia and Saudi Arabia, annual GDP data in million USD at 2017 constant prices was converted to CHF (USD/CHF = 0.9230) and transformed to quarterly data using a cubic spline interpolation.	IFS, CEPII-CHELEM

Two-Stage-Least-Squares

FXI/ GDP	Monthly FXI proxy in million USD, converted to trillion CHF (USD/CHF = 0.9230) and divided by monthly GDP.	Adler et al. (2021), CEPII-CHELEM
Nominal exchange rate	Log of monthly end of period nominal bilateral exchange rate CHF/EUR (increase = appreciation).	IFS
Real exchange rate	Log of monthly end of period real bilateral exchange rate CHF/EUR computed from the nominal bilateral exchange rate and the HICP (increase = appreciation).	IFS
Inflation (differential)	$log(HICP) - log(HICP^*)$, where $HICP$ denotes monthly Swiss inflation and $HICP^*$ denotes monthly inflation in the euro area.	IFS
VSTOXX	Log of end of month EURO STOXX 50 Volatility Index.	Datastream
Energy index	Log of monthly commodity price index for energy, 2016 = 100.	IFS
Metal index	Log of monthly commodity price index for metal, 2016 = 100.	IFS
Food index	Log of monthly commodity price index for food, 2016 = 100.	IFS
Interest rate (differential)	Calculated as $log(1 + i) - log(1 + i^*)$, where i is the 3-month LIBOR rate and i^* is the EA short-term interest rate calculated based on an average of lender's rates supplied by a sample of the 57 most active banks trading in euros.	OECD
GDP per capita (differential)	$log(gdp) - log(gdp^*)$, where gdp denotes the GDP per capita of Switzerland and gdp^* the GDP per capita of the EA. Seasonally adjusted fixed PPP 2015 USD data was converted to CHF (USD/CHF = 0.9230) and transformed to trillion CHF. The quarterly series was transformed into a monthly series using a cubic spline interpolation.	OECD
Trade balance	Current month exports minus imports in trillion CHF (lagged). Data are seasonally adjusted.	SFCA
Trade openness	Monthly imports plus exports over GDP. Quarterly data of real GDP in million CHF was transformed to monthly data using a cubic spline interpolation and was converted to trillion CHF.	SFCA, SECO

Net capital flows/GDP	Net capital flows (Net FDI + Net Portfolio Investment + Net Other Investment) over GDP. Quarterly data in million CHF was converted to trillion CHF and transformed to monthly data using a cubic spline interpolation.	SNB, SECO
Intermediate money	Log of change of monthly M2 in trillion CHF (lagged).	SNB
Imports coverage	Change of SNB's monthly net foreign assets (Foreign Currency Reserves + IMF reserve position + SDR + Gold) in trillion CHF over yearly imports in trillion CHF (lagged).	SNB, SFCA
M2/GDP	Monthly change of M2 divided by GDP (lagged).	SNB, SECO
NFA/M2	Monthly change of SNB's net foreign assets over M2 (lagged).	SNB
Current account/GDP	Monthly change of current account over GDP. Quarterly current account data in billion CHF was transformed to monthly data using a cubic spline interpolation, and was converted to trillion CHF.	SNB, SECO
Sight deposits/GDP	Log of monthly sight deposits of banks at the SNB in million CHF converted to trillion CHF and divided by GDP.	SNB
Foreign currency/GDP	Log of monthly foriegn currency investments of the SNB in million CHF converted to trillion CHF and divided by GDP.	SNB

Appendix 2

POLS Estimation

Table 6.2: Summary Statistics for the POLS Variables

Statistic	N	Mean	St. Dev.	Min	Max
Total Exports	484	2,679.736	2,171.104	691.916	8,676.187
Watches	484	243.906	188.410	12.807	1,119.690
Pharma	484	915.035	833.471	13.789	4,560.353
Non-Pharma	484	1,764.702	1,513.051	412.143	7,032.952
Consumption	484	1,330.007	998.395	302.778	5,300.510
Capital	484	418.883	447.582	44.698	1,827.999
Real Exchange R. 1	484	0.971	0.546	0.011	1.762
Real GDP	484	1,655,421.000	2,689,875.000	64,968.070	12,870,662.000
Real Exchange R. 2	484	10.928	28.823	0.568	124.848

Exports and real GDP are denoted in million CHF. For the real exchange rate, 1: case where increase means CHF appreciation; 2: case where increase means CHF depreciation.

Table 6.3: P-Values of the Unit Root Tests

Variable	LLC	LLC (Diff.)	IPS	IPS (Diff.)
Total Exports	0.331	0	0	0
Capital Goods	0.330	0	0	0
Consumption Goods	0.331	0	0	0
Watches	0.326	0	0.000	0
Pharmaceuticals	0.334	0	0	0
Non-Pharmaceuticals	0.328	0	0.000	0
Real GDP	0.270	0.000	0.016	0
Real Exchange Rate	0.320	0	0.001	0

Diff. refers to the first difference of the variables. LLC refers to the Levin-Lin-Chu Unit-Root Test, IPS to the Im-Pesaran-Shin Unit-Root Test. The null hypothesis of the tests is that the variable of interest is not stationary. Hence, a p-value lower than 0.05 implies that the null hypothesis can be rejected and the variable is stationary. Further unit root tests such as the Breitung (2000) Unit-Root Test were conducted in Stata (since not available in R). Given that they also indicated the presence of a unit root, more weight was given to the outcome of the LLC than the IPS test.

Table 6.4: Random Effects Estimation of Case 1

	All goods	Capital goods	Consumption goods	Pharmaceuticals	Watches	Non-pharmaceuticals
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	0.04	0.02	0.08	−0.05	0.18	0.04
	(0.19)	(0.27)	(0.18)	(0.28)	(0.26)	(0.21)
Bilateral Real Exchange Rate	0.24^{***}	0.38^{***}	0.13^{*}	0.46^{**}	-0.26^{**}	0.23^{***}
	(0.07)	(0.11)	(0.07)	(0.21)	(0.11)	(0.05)
Real GDP	0.30^{***}	0.43^{***}	0.25^{**}	0.62^{**}	0.10	0.26^{***}
	(0.11)	(0.14)	(0.10)	(0.28)	(0.11)	(0.07)
N	440	440	440	440	440	440
R^2	0.57	0.55	0.37	0.54	0.49	0.53

*Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.* Increase in the real bilateral exchange rate represents a depreciation of the CHF.

2SLS Estimation

Table 6.5: Summary Statistics for the 2SLS Variables

Statistic	N	Mean	St. Dev.	Min	Max
FXI/GDP	132	0.033	0.080	−0.095	0.429
Real Exchange Rate	132	0.781	0.053	0.656	0.900
Nominal Exchange Rate	132	0.836	0.082	0.650	0.970
CPI Differential	132	−0.066	0.042	−0.126	0.015
VSTOXX	132	22.350	7.224	11.990	46.680
Energy	132	169.152	49.705	77.528	253.335
Metal	132	144.783	35.376	85.259	234.688
Food	132	107.945	11.543	85.039	132.802
Interest Differential	132	−0.704	0.425	−1.955	−0.057
GDP/Capita Differential	132	0.466	0.013	0.443	0.488
Trade Balance	132	0.00001	0.0005	−0.001	0.001
Trade Openness	132	0.164	0.006	0.149	0.179
Capital Flows/GDP	132	−0.030	0.181	−0.631	0.316
M2	132	0.717	0.176	0.435	0.949
NFA/M2	132	0.567	0.199	0.137	0.821
NFA/GDP	132	2.993	1.220	0.521	4.610

The CPI differential, GDP per capita differential, trade balance, trade openness, and M2 are denoted in trillion CHF.

Table 6.6: Robustness Checks, Second Stage

	Real Exchange Rate	Nominal Exchange Rate	
	Expanded	Normal	Expanded
	(1)	(2)	(3)
Constant	0.001	0.001	0.001
	(0.001)	(0.001)	(0.002)
FXI/GDP	−0.12***	−0.11**	−0.11***
	(0.04)	(0.04)	(0.04)
VSTOXX	−0.0000	−0.0001	−0.0000
	(0.001)	(0.001)	(0.001)
Energy	−0.05	−0.05	−0.05
	(0.04)	(0.04)	(0.04)
Metal	0.08***	0.09***	0.08***
	(0.03)	(0.03)	(0.03)
Food	−0.06	−0.06	−0.06
	(0.05)	(0.05)	(0.05)
Interest Differential	−0.06***	−0.06***	−0.06***
	(0.02)	(0.01)	(0.02)
Trade Balance	−4.65	−3.97	−4.63
	(3.06)	(3.02)	(3.12)
GDP/Capita Differential	−1.24*		−1.23*
	(0.64)		(0.64)
Trade Openness	0.67		0.66
	(0.48)		(0.48)
Capital Flows/GDP	0.01		0.01
	(0.02)		(0.02)
CPI Differential		−0.98*	−0.96
		(0.57)	(0.60)
Weak Instruments	27.51***	28.65***	26.48***
Wu-Hausman	17.34***	17.24***	16.51***
Sargan	1.96	1.64	2.1
F-Statistic	15.58***	11.00***	11.00***
N	132	132	132
R^2	0.21	0.16	0.16
Adjusted R^2	0.14	0.10	0.09

*Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.* Heteroskedasticity- and serial correlation robust standard errors in parantheses. The F-statistic refers to the first stage of the regression. Normal: original dataset. Expanded: larger dataset.

Table 6.7: Robustness Checks of the Proxies, Second Stage

	Real Exchange Rate	
	(1)	(2)
Constant	0.002	0.004**
	(0.001)	(0.002)
Sight Deposits/GDP	−0.05*	
	(0.03)	
Foreign Currencies/GDP		−0.13***
		(0.04)
VSTOXX	0.0003	0.0004
	(0.001)	(0.001)
Energy	−0.04	−0.03
	(0.02)	(0.02)
Metal	0.05	0.08**
	(0.03)	(0.03)
Food	−0.03	−0.05
	(0.06)	(0.06)
Interest Differential	−0.07***	−0.06***
	(0.01)	(0.01)
Trade Balance	−3.74	−3.34
	(3.53)	(2.61)
Weak Instruments	16.54***	33.63***
Wu-Hausman	6.95***	4.91**
Sargan	4.5**	3.74*
F-Statistic	3.83**	13.48***
N	132	132
R^2	0.28	0.38
Adjusted R^2	0.24	0.34

*Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.* Heteroskedasticity- and serial correlation robust standard errors in parantheses. The F-statistic refers to the first stage of the regression. The first column used the Sight Deposits/GDP proxy, the second column the Foreign Currency Investments/GDP proxy.

Prevented Export Sector Damage Calculation

Table 6.8 displays the calculation of the prevented export sector damage which is obtained when the FXI elasticity of the real exchange rate is equal to 1.5%, the value found by Blanchard et al. (2015) and Adler et al. (2019).

Table 6.8: Benefit Calculation with Literature Estimate for FXI Elasticity

Variable During Period 2009-2019	Amount / Share
FXIs	CHF 639.5 billion
Real GDP	CHF 7’312.214 billion
FXI as Percentage of GDP	639.5/7’312.214 = 8.75%
Decrease of Real Exchange Rate by FXIs	8.75 * 1.5% = 13.125%
Export Increase due to FXIs	13.125 * 0.24% = 3.15%
Exports in Absence of FXIs	2’997.7/1.0315 = CHF 2’906.15 billion
Benefit of FXIs	2’997.7 – 2’906.15 = CHF 91.55 billion
Difference between Costs and Benefits	639.5 – 91.55 = CHF 547.95 billion

Table 6.9 displays the calculation of the prevented export sector damage which is obtained when the real exchange rate elasticity of exports is equal to 4.2%, the value found by Thorbecke and Kato (2018).

Table 6.9: Benefit Calculation with Literature Estimate for Real Exchange Rate Elasticity

Variable During Period 2009-2019	Amount / Share
FXIs	CHF 639.5 billion
Real GDP	CHF 7’312.214 billion
FXI as Percentage of GDP	639.5/7’312.214 = 8.75%
Decrease of Real Exchange Rate by FXIs	8.75 * 11% = 96.25%
Export Increase due to FXIs	96.25* 0.42% = 40.425%
Exports in Absence of FXIs	2’997.7/1.40425 = CHF 2’134.74 billion
Benefits of FXIs	2’997.7 – 2’134.74 = CHF 862.96 billion
Difference Between Costs and Benefits	639.5 – 862.96 = CHF -223.46 billion