Exchange rate shocks and asset prices: the role of currency denomination*

Romain Baeriswyl[a], Alex Oktay[a,1], Marc-Antoine Ramelet[a,*]

[a]*Swiss National Bank, Boersenstrasse 15, 8001 Zurich, Switzerland*

Abstract

We study the reaction of asset prices to exchange rate shocks in Switzerland and argue that their response is largely driven by international parity movements. In particular, we identify exogenous variations in the Swiss franc from monetary policy announcements to estimate asset price responses, and exploit the staggered introduction of cross-listed stocks to measure the relative importance of valuation effects. Our causal evidence suggests that cross-listing markedly amplifies a firm's stock price response to the exchange rate: the mere presence of the cross-listing explains up to 41% of the (positive) average return that follows a currency depreciation. Vice-versa, cross-listing explains 31% of the (negative) average return observed after a currency appreciation. Firm heterogeneity reveals that the prices of stocks with foreign-denominated cash flows are considerably more sensitive to the exchange rate. As a result, stock market movements in small open economies that follow central bank announcements should be interpreted with caution as they reflect both economic information and more mechanical parity adjustments.

Keywords: International asset pricing, Law of one price, Exchange rates, Cross-listing

JEL: F31, G12, G15

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*Corresponding author.

Email addresses: romain.baeriswyl@snb.ch (Romain Baeriswyl), alexokta@sas.upenn.edu (Alex Oktay), marc-antoine.ramelet@snb.ch (Marc-Antoine Ramelet)

[1]Present address: University of Pennsylvania, Department of Economics, 133 South 36th Street, Philadelphia, PA 19104, United States.

1. Introduction

Movements in exchange rates are generally associated with movements in asset prices. While the impact of asset prices on exchange rate determination is arguably well-understood now, the inverse channel remains harder to disentangle. Do asset prices react to exchange rate movements? If so, does it reflect changes in economic fundamentals or more mechanical valuation effects?

We argue there are two general channels through which exchange rates can affect asset prices. First, an *economic conditions* channel, where currency movements have an impact on the whole economy via changes in export and import prices, domestic and foreign demand, relative borrowing conditions, international competition, and other macroeconomic factors. These macroeconomic changes may affect the sovereign risk of default and expected future emissions (thus affecting sovereign bond prices), as well as firms' risk of default (thus affecting corporate bond and stock prices) and expected profits (thus affecting stock prices). They should not significantly affect commodity prices however, since the value of a commodity relative to the same commodity produced in other countries has no reason to be tied to the domestic economic performance assuming that it is easily tradable. Second, a *currency denomination* channel, where the denomination of the asset and its cash flows drives parity movements. For instance, one can expect commodity prices to react one-to-one to the exchange rate because of the law of one price, given their perfect foreign-denominated substitutes. The same effect might apply to stocks with cross-listings, which offer a perfect foreign-denominated substitute, and to a lesser extent also to stocks without cross-listings, as long as foreign firms might provide a reasonable substitute for them. Moreover, the international value of firms' expected profits might be further affected depending on the denomination of their cash flows, in turn affecting their stock prices. These parity movements may be made via portfolio re-balancing and arbitrage corrections.

We explore these channels empirically using Swiss asset prices and the Swiss franc. This offers four advantages. Perhaps most importantly, as a small open economy that relies extensively on trade, Swiss economic activity is highly sensitive to the exchange rate. The effects of Swiss franc movements on nominal and real activity have been extensively studied;[2] As such, it

[2]Examples include the effect on import prices and expenditures (Auer et al., 2021), on consumer prices

is clear that exchange rate movements must have a larger and more easily identifiable effect in Switzerland than in countries that are less open. Additionally, Switzerland is home to several companies whose economic activity takes place mainly abroad, Nestlé being a perfect example with over 98% of its sales (and the majority of its production) being outside Switzerland. This allows us to analyze how differences in the denomination of cash flows might impact stocks sensitivity to the exchange rate. It would be difficult to find companies in large currency zones with such a large proportion of their cash flows in foreign currencies, which would make it impossible to clearly separate the effect of economic conditions from that of currency denomination. Moreover, 54 Swiss firms are now cross-listed in the United States, which offers enough variation for a causal analysis of the effects of cross-listing on that sensitivity. Switzerland imposes no capital controls or foreign ownership restrictions, and a large share of its financial assets are foreign-owned, such that very few frictions impair our analysis of the cross-listing arbitrage. Lastly, the Swiss central bank openly communicates important news about the Swiss franc through its announcements, which at times led to large exchange rate movements. This forms the basis of our identification strategy.

First, we trace the response of various asset classes to exogenous movements of the Swiss franc. Identifying exogenous exchange rate shocks is challenging since exchange rates result from the interaction of many global macroeconomic and financial flows. To overcome this challenge, we focus on the exchange rate movements on the monetary policy announcement days of the Swiss National Bank (SNB). As the SNB's announcements are typically the only significant domestic economic event on these days, exchange rate movements are, after controlling for interest rate surprises and changes in the nominal effective exchange rate of foreign currencies, close to pure exogenous shocks. Prime examples are the unexpected introduction of the minimum exchange rate of 1.2 Swiss francs against the euro decided by the SNB on September 6, 2011, and its unexpected discontinuation on January 15, 2015.[3] The Swiss franc depreciated by 8.8% against the US dollar on September 6, 2011, and it appreciated by 10.8% on January 15, 2015, yielding two exogenous exchange rate shocks. We extend this idea to all SNB monetary policy announcements, which all conveyed some information on the Swiss franc, to build a series of

(Oktay, 2022), on product quality and export prices (Freitag and Lein, 2023), on investor and firm behavior (Efing et al., 2022) and on the current account (Eugster and Donato, 2022).

[3]See Jermann (2017).

exogenous shocks and obtain clean estimates of how asset prices react to the exchange rate.

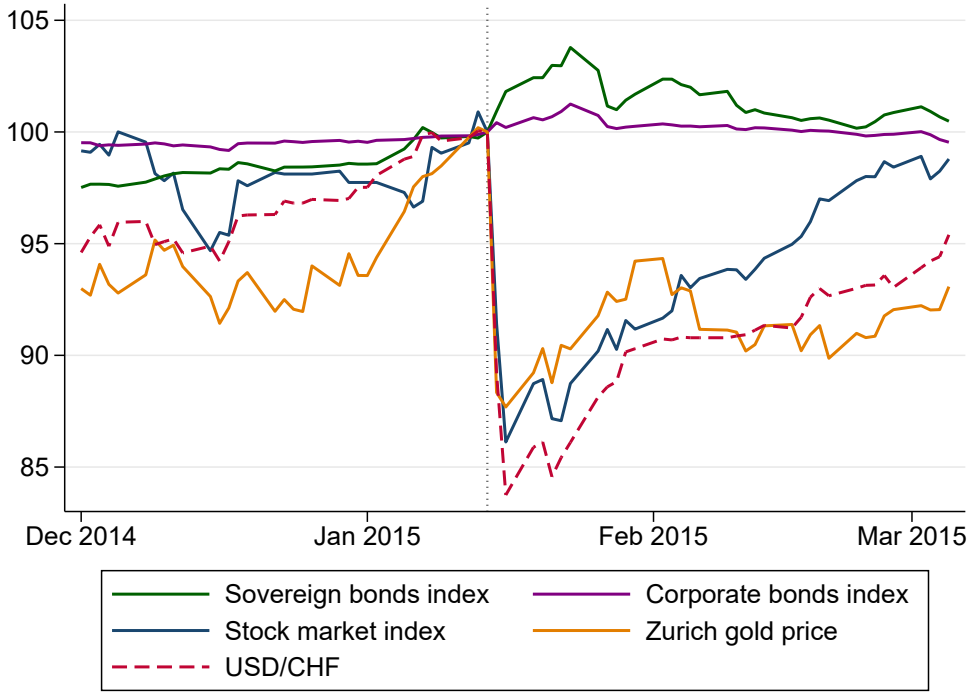
We find that a domestic currency appreciation (depreciation) decreases (increases) domestic stock and gold prices but has no effect on bond prices. This can be seen in Figure 1, which shows a very differentiated response across asset classes to the large and unexpected Swiss franc appreciation that took place on January 15, 2015. As is standard for the Swiss franc, we use the direct quotation throughout the paper, that is the USD/CHF instead of CHF/USD, which means that a lower exchange rate represents a domestic currency appreciation.[4] While the price of some assets such as bonds hardly reacted at all to changes in the exchange rate, the price of other assets such as gold or stocks reacted strongly. We show that this marked difference holds across the whole sample of 106 currency shocks that span the years 2000 to 2022 using local projections. In particular, we estimate that a 100 basis point (bp) increase of the USD/CHF is associated with an immediate 101 bp increase in gold prices, a 35 bp increase in stock prices, and a 0 bp reaction of corporate and sovereign bond prices. The response of asset prices is persistent: the 60-day average response since the shock is 63 bp, 35 bp, -5 bp, and 1 bp for gold, stocks, sovereign bonds, and corporate bonds, respectively.

Second, we exploit the staggered introduction of cross-listings in a difference-in-differences (DID) setting to evaluate whether the introduction of a perfect foreign-denominated substitute for stocks affects their sensitivity to exchange rate shocks. Doing so hints at the importance of the currency denomination channel relative to the economic conditions channel. Over our sample period of 2000–2022 and out of 212 publicly traded companies, 49 Swiss firms became cross-listed on the US stock market via American Depository Receipts (ADRs) – which brought the total of cross-listings to 54 at the end of the sample period. While it is clear that bigger and more international firms have more incentives to be cross-listed, we argue that the exact timing of the cross-listing is exogenous and can thus be used as a valid treatment. We further relax the parallel trend assumption by using a synthetic DID approach, which artificially matches stock prices to a synthetic control group mimicking the stock's reaction to exchange rate shocks.

We find that cross-listing significantly amplifies the sensitivity of stock prices to exchange rate shocks. The effect is sizeable: approximately one-third of the domestic stock price move-

[4]See, e.g., Freitag and Lein (2023) and Auer et al. (2021). The SNB notably uses the direct quotation in its communication.

Figure 1: Swiss asset prices around the January 2015 Swiss franc appreciation



Notes: Series in Swiss francs and indexed to 100 on the day before the January 15, 2015, announcement (vertical line), when the SNB discontinued the EUR/CHF minimum exchange rate. The indexes used are the S&P Swiss Sovereign Bond Index, S&P Switzerland IG Corporate Bond Index, Swiss Performance Index, and Zurich 995 gold price. Source: Refinitiv Datastream.

ments that follow exchange rate shocks can be attributed to cross-listing. Specifically, about 41% of the positive returns of the treated stocks that follow a currency depreciation can be attributed to the cross-listing (equivalently, the cross-listing amplifies the returns by 69%) and about 31% of the negative returns that follow a currency appreciation can be attributed to them (i.e. amplifies the returns by 45%). Because cross-listing enhances the degree of substitutability of domestic stocks with their foreign peers, the domestic price of cross-listed stocks reacts much more strongly to the exchange rate. This is illustrative of the law of one price, which states that the domestic listing should react negatively to a currency appreciation while the foreign listing should react positively. It confirms that the currency denomination of equity is a major driver of the sensitivity of stock prices to exchange rate shocks, jointly with the denomination of its cash-flows. This result is not driven by changes in risk premiums, as we find that credit spreads (measured by the price of corporate bonds) do not respond to the exchange rate shocks.

Lastly, we analyze several dimensions of stock heterogeneity and provide evidence that the

response of stock prices to exchange rate shocks is largely driven by the currency denomination of the underlying cash flows. Because the exact decomposition of cash flow currencies or country of production is not part of any of the mandatory filling requirements for Swiss firms, neither in their financial nor cash flow statements, we use several proxies for the share of foreign cash flows.[5] Mainly, we use the ratio of foreign sales over total sales, which should accurately approximate the share of foreign cash flows for most firms, and supplement it with the firms' market capitalisation, industry, product exchange rate pass-through, and cross-listing. The response is increasing with the proportion of cash flows denominated in foreign currencies. We show that the stock prices of international foreign-oriented firms are close to five times more sensitive to the shocks than those of domestically oriented firms. In line with this, firms whose products have a higher pass-through to consumer prices, that are cross-listed in the US, that are in more international sectors (such as healthcare, tourism, retail, industrial, and technology) and that are larger are more sensitive to exchange rate shocks. All of these characteristics are directly linked to the proportion of foreign cash flows of firms and to how foreign-oriented they are, though we cannot formally test the accuracy of the proxy. Accordingly, our results suggest the opposite of the hypothesis that asset prices fall after a currency appreciation because of worsened domestic economic conditions. If that were true, domestically oriented firms should be more impacted by the shocks than firms that have close to no domestic business and for which the domestic currency does not matter for the production or sale of their products.

Taken together, these results are suggestive of the currency denomination channel though distinct margins. The difference in response between gold (no cash flows, no domestic exposure, direct foreign substitute) and bonds (domestic cash flows, domestic exposure, no foreign substitutes) is indicative that the degree of substitutability of the domestic asset with foreign-denominated ones drives the response to the exchange rate rather than domestic economic conditions, regardless of cash flow denomination. The introduction of a cross-listing provides more causal evidence for that margin in cases where assets have foreign cash flows: improving the international substitutability of a stock significantly amplifies sensitivity to exchange rate shocks. Cross-sectional heterogeneity across firms suggests that foreign cash flows also play a

[5]We additionally do not find any evidence of the voluntary disclosure of this information for any major Swiss firm, nor is it part of the mandatory filling of firms cross-listed on the US market via ADRs.

part irrespective of foreign substitutability, though we cannot observe the cash flow currency directly.

Our analysis thus overall suggests that the currency denomination channel drives a significant and large part of the reaction of asset prices to exchange rate shocks. That is, we argue that a sizeable portion of the movements in asset prices following currency appreciations or depreciation in small open economies like Switzerland are mechanical parity movements akin to the law of one price, which are unrelated to changes in the underlying state of the economy.

To our knowledge, we are the first to highlight the importance of this currency denomination channel. Related evidence can be found in Lane and Shambaugh (2010), who show that the currency exposure of firms' balance sheets can partly explain the valuations of net foreign assets. In a similar vein, Fung et al. (2022) show that a flexible exchange rate regime better enforces the price parity of cross-listed Chinese stocks. We also contribute to the understanding of asset pricing. By providing conclusive evidence of a thus-far undocumented transmission mechanism of the exchange rate on stock prices, we give an international perspective on asset pricing (as suggested by Brunnermeier et al., 2021).[6] The results that we obtain for Swiss firms have some external validity for other countries since the currency denomination channel operates for any firm with cash flows denominated in foreign currencies or a foreign cross-listing.

In Section 2, we discuss the theory surrounding international asset pricing and the law of one price. Section 3 describes the identification of exchange rate shocks. In section 4, we compute the impulse responses of Swiss asset prices to exchange rate shocks. In section 5, we use a synthetic difference-in-differences to identify the causal impact of cross-listing on the exchange rate sensitivity of stocks. Section 6 analyzes the heterogeneity of exchange rate sensitivity across firms. Section 7 concludes the paper.

2. Theory on asset pricing and exchange rates

A large strand of the literature studies the relationship between exchange rates and asset prices. In the first direction, asset prices are important determinants of exchange rates, which has been extensively studied through the lens of exchange rate determination (see, e.g., Hau

[6]Nestlé was used by Stulz (1995) to argue that the international version of the capital asset-pricing model was needed to estimate the costs of capital in small-open economies.

et al., 2010, Pavlova and Rigobon, 2007, Hau and Rey, 2006, Hau and Rey, 2004, Gavin, 1989 and Stulz, 1987). It is however the converse relationship that we study in this paper, that is the determination of asset prices based on exchange rates.

On the financial side, it is well-known that assets are priced globally (Karolyi and Stulz, 2003) and that the cost of capital in small-open economies depends on exchange rates (see, e.g., Stulz 1995 for Switzerland). Asset prices have been shown to incorporate exchange rate risk (Dumas and Solnik, 1995; Bodnar and Gentry, 1993; Adler and Dumas, 1984), and financial valuation models often include a currency risk premium.[7] This relationship has been widely studied empirically, concluding that firms tend to significantly lower their exposure through hedging (Bartram et al., 2010).[8] Despite hedging, considerable financial research has shown that asset prices and exchange rates are strongly correlated, focusing on measuring their cointegration rather than the reasons underlying the comovements.[9] The macroeconomic literature provides additional answers on the mechanisms through which exchange rate shocks might affect asset prices. Exchange rate shocks affect firms directly via their debt valuation (Aguiar, 2005), invoice currency and consumer prices (Auer et al., 2021) as well as general behavior (Dominguez and Tesar, 2006). Exchange rate shocks also impact the macroeconomy in which firms operate since domestic fundamentals are tied to the exchange rate (as shown in Engel and West, 2005). This includes an effect on aggregate demand (Gavin, 1989), competitive and import spaces (Hodder, 1982) as well as terms of trade (Pavlova and Rigobon, 2007). In terms of direction, a domestic depreciation tends to lead to a macroeconomic expansion (Fukui et al., 2023). All in all, these macroeconomic changes are bound to ultimately affect firms and asset prices.

These mechanisms cannot fully explain the empirical reaction of international firms to currency shocks. If it were true that exchange rate shocks affected asset prices because they lead to a change in domestic economic conditions, large international companies that have close to no domestic business would be unaffected by a domestic currency shock. However, we will

[7]For instance, the widely used international capital asset pricing model pioneered by Solnik (1974), Stulz (1981) and Adler and Dumas (1983) includes a currency risk premium based on firms' foreign exchange rate exposure.

[8]The literature commonly refers to this as the exchange rate exposure puzzle, since firms' exposure has been observed to be much smaller empirically than what financial theory would suggest.

[9]See, e.g., Bahmani-Oskooee and Saha 2015; Phylaktis and Ravazzolo 2005; Ajayi and Mougoué 1996.

show that the inverse relationship is observed in our dataset, with large foreign-oriented firms being more sensitive to domestic currency shocks than purely domestic firms. Our results reveal another transmission mechanism from exchange rate shocks to asset prices: the currency denomination channel. Because firms are listed in the domestic currency, a currency shock immediately impacts the international relative value of domestic firms' equity. That is, a currency appreciation makes domestic equity relatively more expensive, while a currency depreciation reduces its international value. As a corollary, firms that are listed on several markets should react more strongly since cross-listing makes it easier for foreign investors to compare the values of similar companies. Even single-listed firms that are large enough to be comparable to some foreign firms will be substituted by investors for those foreign assets when the domestic currency appreciates (or attract new investors when the currency depreciates).

The law of one price is thus a key mechanism to our analysis. In efficient markets, securities or commodities listed on multiple financial markets must have equalized local prices. Otherwise, arbitrage opportunities would arise. For example, if the price of gold differs between two trading venues, arbitrageurs will buy gold on the cheap market to sell it at a profit on the expensive market. Arbitrage incentives will diminish as prices adjust and will dissipate entirely when prices equalize. This relationship tends to hold well empirically up to some exceptions. Frictions between markets, such as transaction and transportation costs, different trading hours or legal restrictions, limit arbitrage opportunities and may yield persistent deviations from the law of one price, as shown in Shleifer and Vishny (1997).

2.1. The law of one price with two currencies

By extension, the law of one price can apply when the price of an asset is expressed in two currencies:

$$p_t^{CH} = p_t^{US} \times USDCHF_t \,. \tag{1}$$

The price of an asset in domestic currency p_t^{CH} (in our case the Swiss franc) must be equal to the price of the same asset in foreign currency p_t^{US} (in our case the US dollar) translated to the domestic currency. Otherwise, there would be arbitrage opportunities. Importantly, the law of one price is silent on whether it is the domestic price or the foreign price that is adjusted in the wake of exchange rate movements. For the law of one price to hold, an appreciation of the domestic currency ($USDCHF \downarrow$) must be met with a decrease in the domestic price $\left(p_t^{CH} \downarrow\right)$

or an increase in the foreign price $\left(p_t^{US} \uparrow\right)$ or a combination of both.[10]

The question of whether it is the domestic price or the foreign price that adjusts to exchange rate movements remains relevant even if the asset is not actually quoted and traded in foreign currency. As we will show, however, direct trading of an asset in foreign currency (through American Depositary Receipts for instance) influences how exchange rate movements affect domestic and foreign prices.

The reaction of domestic and foreign prices to exchange rate movements is mainly driven by the denomination of the asset and related cash flows. Two boundary cases illustrate the role of the denomination in the adjustment of the domestic price to an exchange rate shock.

On the one end of the spectrum, real assets such as gold do not derive their value from any cash flows. Since these assets do not derive their value from any monetary flow, their price in domestic currency will fluctuate according to movements in the domestic exchange rate to satisfy the law of one price. If the domestic currency appreciates by 10% against foreign currencies, the price of gold in the domestic currency will decline by 10% while the price of gold in foreign currencies will remain, all else being equal, stable.

On the other end of the spectrum, nominal assets such as bonds derive their value from being a claim on a nominal amount of money. The domestic price of these assets will not fluctuate with movements in the domestic exchange rate, unless such movements affect the creditworthiness of the debtor. If the domestic currency appreciates by 10% against foreign currencies (and assuming the creditworthiness of the debtor is unchanged), the domestic price of a bond will remain unchanged while its price in foreign currency will increase by 10% so that the law of one price holds. Since domestic currency is worth 10% more, 10% more foreign money is needed to buy the domestic bond.

Between the two boundary cases provided by gold and bonds lie stocks, which are real assets whose value depends on monetary cash flows. An exchange rate shock affects the value of a domestic share to the extent that it affects its cash flows in the domestic currency.

[10]While it is technically possible that the law holds if both move in the same direction, this would require an exchange rate pass-through to domestic asset prices greater than 1, which we do not observe in the data (see, e.g., Oktay, 2022 for Switzerland). We thus focus on the incomplete pass-through case.

2.2. Economic conditions vs. currency denomination hypotheses

There are two hypotheses that can rationalize why stock prices react to exchange rate movements. The first hypothesis states that stock prices react to an exchange rate shock because of its effect on the economic conditions of the company. According to this *economic conditions* hypothesis, stock prices fall after an appreciation of the domestic currency because domestic economic activity is slowed by a stronger currency. This could be due to shocks to macroeconomic fundamentals (following Engel and West, 2005), aggregate demand (following Gavin, 1989) or competitive space and import prices (following Hodder, 1982). The second hypothesis states that stock prices react to an exchange rate shock because of the denomination of the firm's cash flow and equity. According to this *currency denomination* hypothesis, stock prices fall after an appreciation of the domestic currency because the value of foreign cash flows expressed in domestic currency falls and the value of equity expressed in foreign currency increases.

Although these hypotheses are not mutually exclusive, they provide a very different assessment of the effect of an exchange rate shock on stock prices and the economy. If the domestic stock market falls in the wake of an appreciation of the domestic currency, the *economic conditions* hypothesis will infer a future economic slowdown, while the *currency denomination* hypothesis will simply observe that, because of its appreciation, less domestic currency is needed to acquire domestic companies. The economic interpretation of stock price movements following an exchange rate shock is therefore very different depending on the prevailing hypothesis.

Depending on their business model, firms might be more sensitive to the *economic conditions* or the *currency denomination* hypothesis. Swiss firms follow three types of business model that each come with distinct predictions.

First, the stock price of domestically oriented companies with a strong domestic economic activity (such as Swiss Prime Site, the leading real estate company in Switzerland) should only react if the exchange rate shock affects domestic economic activity, while their cash flows, all denominated in domestic currency, would not be subject to any valuation effect. Movements in the stock price of these companies would support the economic conditions hypothesis.

Second, the stock price of international companies with strong foreign economic activity (such as Nestlé) should react to the exchange rate shock independently of its effect on domestic economic activity and simply because of its denomination effect on foreign currency profit. Even

if the foreign currency profit remains stable (because all expenses and income are in foreign currencies), an appreciation will lead to a decline in profit in domestic currency. Movements in the stock price of these companies would support the denomination effect hypothesis.

Third, the stock price of exporting companies (such as Swatch) should react to the exchange rate shock because of a double-denomination effect on revenues and profit. If expenses are denominated in domestic currency and revenues in foreign currencies, an appreciation will lead, first, to a decline in the profit in foreign currencies (because expenses expressed in foreign currencies will increase) and, second, to a decline in the profit in domestic currency. Movements in the stock price of these companies would support the denomination effect hypothesis, particularly if they are stronger than movements of stock prices of international companies (and stronger than that of domestically oriented companies).

The currency denomination channel thus incorporates two margins. On one side, the degree of substitutability of the asset with foreign-denominated counterpart can prompt parity movements akin to the law of one price. On the other, the value of a firm with foreign cash flows will immediately be reevaluated when exchange rate movements arise. We note that cash flow currency themselves are not sufficient to separate those channels: a firm with large foreign cash-flows will both have closer foreign substitutes (since its business is less idiosyncratic and competes with other foreign firms) and be more likely to suffer from reevaluation effects. Those two margins cannot be fully disentangled, though our various exercises will speak more closely to one or the other, hence our joint treatment of both as a single channel.

What effect can we expect from companies hedging their exchange rate risk and from the denomination of invoices? Bartram et al. (2010) show that firms isolate themselves from foreign exchange rate exposure via hedging and provide explanations for the relatively low exposure that is observed empirically. We have omitted the role of hedging thus far, which partially dampens the currency denomination hypothesis. Because firms may hedge their exchange rate risk related to their cash flows or exposures in foreign currencies, hedging may attenuate the effect of exchange rate shocks on equity prices through the currency denomination hypothesis. Firms, however, do not hedge their exposure to the changes in macroeconomic conditions that result from exchange rate shocks. Therefore, hedging should not affect the response of equity prices to exchange rate shocks through the economic condition hypothesis. Moreover, as firms can hedge their exposure only over a limited period of time, the effect of hedging of equity

prices should be limited. We have also omitted the role of the invoicing currency of firms. Auer et al. (2021) show that the invoicing currency affects how fast firms adjust their prices following an exchange rate shock. While the invoicing currency determines who gains or loses on the exchange rate for a particular invoice between buyer and seller, the invoicing currency does not affect the exchange rate effect on future economic relationships. For example, it would be naive to believe that an exporting company can protect itself from a currency appreciation simply by choosing the appropriate invoicing currency. The invoicing currency therefore has only a fleeting effect on a company's exposure to exchange rates.

Even if the domestic asset is actually not traded in foreign currency, the law of one price (equation 1) can be computed to assess how domestic and foreign assets react to exchange rate movements, since the two are relatively substitutable. However, most large Swiss stocks are cross-listed in the US via American Depositary Receipts (ADRs), offering a perfect foreign-denominated substitute to domestic stocks. If it were true that the *currency denomination* effect dominated, the introduction of an ADR would markedly amplify the reaction of the domestic stock price to the exchange rate as to maintain the law of one price with its foreign counterpart. Our analysis thus exploits the adoption of ADRs to estimate the relative importance of the two channels since its effects on domestic stock prices may only arise from parity movements.

3. Isolating exchange rate shocks

We aim to disentangle movements in asset prices that are caused by the exchange rate itself, as opposed to those that correlate but are not caused by it. For instance, a global risk episode could make the Swiss franc appreciate by safe haven effects and decrease Swiss asset prices because of lower global demand, making it appear like a negative correlation between the two. Conversely, positive news about Swiss GDP could attract new capital and raise both equity and the Swiss franc, making it appear like a positive relationship. In both cases, macroeconomic shocks are a confounding object that we aim to eliminate to isolate how and why the exchange rate moves asset prices.

One of our contributions is thus to identify exchange rate movements that are true shocks in the sense that they reflect unexpected news on the domestic currency itself. Identifying exchange rate shocks proves challenging since exchange rates are the result of overall economic activity. Real exchange rates are pinned down by the ratio of domestic and foreign prices in

international real business cycle models (Backus et al., 1992). In the New Keynesian literature (Gali and Monacelli, 2005) and in international asset pricing models (Pavlova and Rigobon, 2007), the terms of trade determine the real exchange rate. Differences in money supplies and interest rates (Stulz, 1987 and Obstfeld and Rogoff, 1995) also affect the exchange rate. These determinants are in turn driven by underlying fundamental shocks, so that the observed exchange rate movements reflect a myriad of unexpected changes in the economy. This makes it challenging to isolate *exogenous* shocks to the exchange rate that are orthogonal to the rest of the newly available economic information.[11]

A prevalent type of exogenous exchange rate movements used in the literature are those following policy changes and specific currency regimes. For instance, Fukui et al. (2023) use regime-induced changes by comparing pegged and floating currencies. In the same vein, Auer et al. (2021) uses the 2015 regime change surrounding the Swiss franc as an exogenous shock. While such shocks are well-identified and have strong internal validity, they are very rare. In the case of Switzerland, only two major currency regime changes have been observed since 2000. They were accompanied with large exchange rate movements, which may not be representative of smaller and more usual movements. We follow the spirit of this literature but generalize it to more frequent shocks by using monetary policy announcements, which contain information about the exchange rate that is unrelated to monetary policy or standard information effects.

3.1. Estimation procedure

We focus on a specific subsample of exchange rate movements, namely those that take place on the monetary policy announcement days of the Swiss National Bank (SNB). This allows us to select movements that are not the result of a mixed variety of shocks. We accordingly draw on the by-now extensive research agenda (see Miranda-Agrippino and Ricco, 2021, Jarociński and Karadi, 2020 and Ramey, 2016 for a literature review) that uses time windows around announcements to identify monetary policy shocks. Doing so allows us to focus on the unanticipated, and thus exogenous, component of monetary policy announcements instead of their preemptive effects. The exchange rate plays an important role for Swiss monetary policy. As

[11]This is particularly true when estimating the effect of the exchange rate on stock prices because these prices reflect the current information set of market participants (see Phylaktis and Ravazzolo, 2005 for an application via Granger causality and cointegration).

such, SNB announcements were accompanied by rich exchange rate variations during our sample period. Because SNB announcements are typically the only significant domestic economic event on those days, monetary policy news are not contaminated by other domestic shocks. Our approach builds on the literature on exogenous exchange rate shocks, which typically uses a single large shock as an event study,[12] by instead using a series of shocks.

We construct a series of movements in the Swiss franc as the daily change in the USD/CHF bilateral exchange rate on SNB announcement days. This bilateral rate is relevant for the Swiss economy and accordingly has a nontrivial weight in nominal effective exchange rate measures. Its movements are also highly correlated with those of the predominant bilateral rate for the Swiss franc (namely, the EUR/CHF), in particular on SNB announcement days.[13] Even more important for our analysis, Swiss stocks that are quoted on multiple exchanges are typically listed in the US[14] (either on the NYSE, the Nasdaq or over-the-counter) which justifies the use of the USD/CHF rather than the EUR/CHF. In any cases, we use the direct quotation as is usually done for the Swiss franc: a decrease of the exchange rate thus implies a domestic appreciation, and an increase implies a domestic depreciation.

We then purge those shocks of movements that are due to monetary policy surprises, central bank information effects, and non-domestic exchange rate movements in order to focus on pure domestic exchange rate surprises. Doing so is necessary for the following reason. If we were to regress asset prices reaction to the observed movement in the USD/CHF, would we be measuring the reaction of asset prices to *(i)* a monetary policy surprise that moves both the exchange rate and asset prices, *(ii)* information effects that move both of them, *(iii)* a foreign shock that moves both of them, or *(iv)* the true response of asset prices to a movement in exchange rates that is not due to another confounding variable? Our aim is to disentangle the fourth object from the first three.

To do so, the purged series z_t is the residual obtained from regressing the observed USD/CHF movement (on announcement day t) against the three key other information provided on mon-

[12] In the case of Switzerland, the unexpected 2015 Swiss franc appreciation is used idiosyncratically in Freitag and Lein (2023), Efing et al. (2022), Eugster and Donato (2022), Oktay (2022) and Auer et al. (2021) among others.

[13] On these days, the correlation coefficient of the bilateral rate movements (USD/CHF and EUR/CHF) is 0.88.

[14] A few Swiss firms are also cross-listed in the euro area and in the United Kingdom. We focus on cross-listing in the US since it is by far the most common type of cross-listing.

etary policy announcement days:

$$\Delta \text{USDCHF}_t = \alpha + \beta_1 \Delta \text{NEER}_t + \beta_2 \Delta \text{MoPo}_t + \beta_3 \Delta \text{Info}_t + z_t \,. \tag{2}$$

That is, we first control for the interest rate surprises (MoPo_t) that take place on SNB announcement days by using the shocks of Koeniger et al. (2022).[15] We then control for information effects (Info_t) by computing the Bu et al. (2021) and Ciminelli et al. (2022) shocks for Switzerland that are based on the information contained in the yield curve. This identification through the heteroskedasticity approach relies on only one key structural assumption: that the variance of the monetary component of a series is higher on central-bank announcement days. The assumption is adequate for Switzerland since SNB decisions have been shown to have a sizeable impact on asset prices (Ranaldo and Rossi, 2010). Online Appendix A provides a detailed description of the approach, which we replicate with Swiss data on SNB announcement days. It is worth noting that controlling for information effects does not eliminate the exchange rate shocks. This is not surprising given that the SNB notably discusses the exchange rate during its announcements, in addition to communicating its interest rate decision. In line with this, our information shocks capture information regarding interest rates and not information linked to exchange rates. Lastly, movements in the USD/CHF reflect movements in both the Swiss franc and US dollar; we thus control for the US dollar nominal effective exchange rate (NEER_t) computed by the BIS. By doing so, we isolate the Swiss franc part of the bilateral rate movements.[16] In our specifications, we also control for the exchange rate movements that took place since a given announcement. We thus trace the effect of a shock over the next days, accounting for the subsequent movements in the Swiss franc.

Figure 2 plots the daily changes (in percentage points) that took place on SNB announcement days, together with the corresponding series that was further purged from monetary,

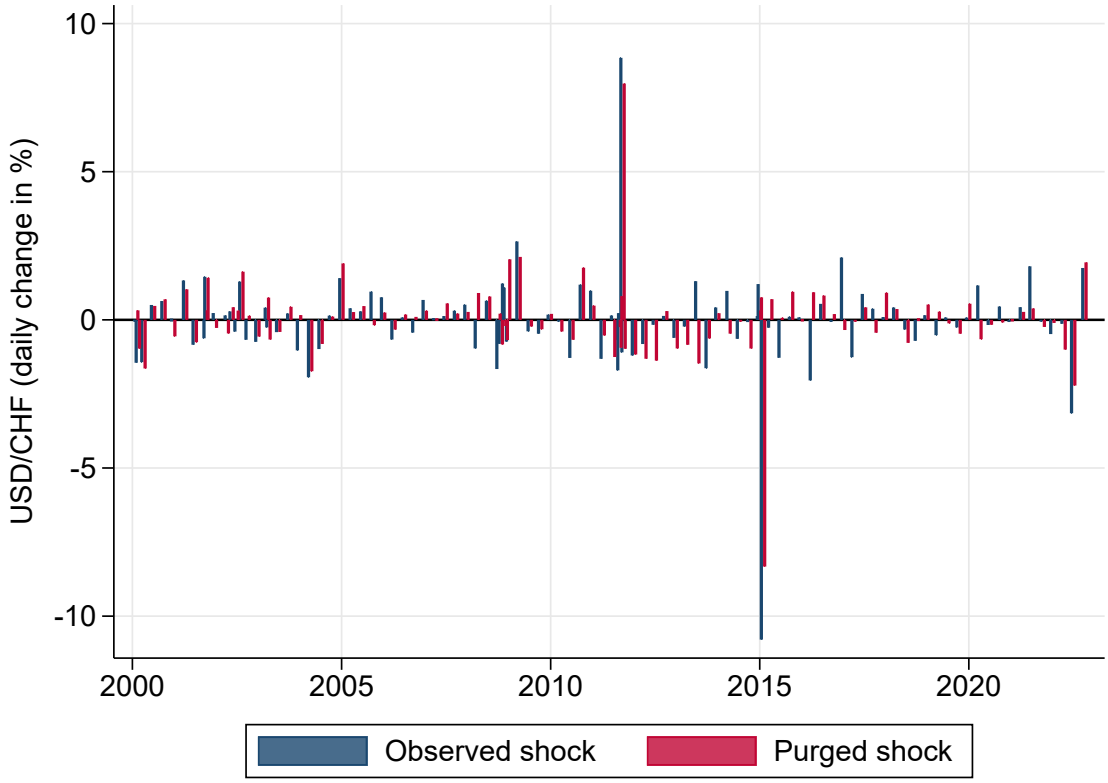
[15] Koeniger et al. (2022) extract the unexpected movements in short-term rates on SNB announcement days from futures contracts. Following Miranda-Agrippino and Ricco (2021), the shocks of Koeniger et al. (2022) are purged from potential auto-correlation. Online Appendix H shows that all results are robust to using an alternative control method for these shocks, namely the Bu et al. (2021) monetary policy shocks.

[16] Instead using the Swiss franc NEER to compute the exchange rate shocks directly is not an option. The Swiss franc NEER is almost entirely determined by the USD/CHF and EUR/CHF via the large respective trade positions. It therefore includes movements in the US dollar and the euro. On the other side, the US dollar NEER contains several bilateral exchange rates, to which the Swiss franc does not contribute substantially. It thus captures US dollar movements irrespective of the Swiss franc.

information, and foreign exchange rate effects. The series contains a total of 106 shocks. While the observed shocks $\Delta\text{USDCHF}_t = 100(\text{USDCHF}_t/\text{USDCHF}_{t-1} - 1)$ and the purged series z_t displayed in the figure are highly correlated (the correlation coefficient is 0.84), they differ in some key episodes and may even have different signs in rare occasions. Two noticeably large shocks are those in September 2011 and January 2015, when the minimum EUR/CHF exchange rate was introduced and discontinued, respectively. These two shocks highlight the adequacy of studying the Swiss case. The exchange rate movements were not only large, they were also completely unexpected by financial market participants, in turn providing exogenous variations (consistent with this, the purged series have similar magnitudes in Figure 2). While these two shocks are key parts of the identification strategy, the results presented in this paper are qualitatively robust to removing either of these extremely large shocks (see Online Appendix G). Removing the 2011 shock does very little to the results, which remain similar in magnitude but lose some power (the difference-in-differences analysis in particular loses the most and has large error band). Removing the 2015 shock reveals more differences: the response of large capitalization and cross-listed firms is dampened compared to the full sample, though it remains significantly larger than small capitalizations and single-listed firms. Error bands are once again larger, especially so for the difference-in-differences analysis. Together, these results imply that the two shocks are not fully necessary for the qualitative part of our results, since all of the signs and most of the magnitude remain, but they significantly improve inference especially for our difference-in-differences estimates.

Decomposing some of the most significant episodes of Swiss monetary policy announcements illustrates the need for our identification scheme. First, the September 2011 announcement of a EUR/CHF floor was an almost-pure exchange rate announcement: it did not carry an interest rate decision or other significant macroeconomic news. As such, our identified shock (8.0%) is extremely close to the observed exchange rate differential (8.8%). The discontinuation of the floor in January 2015 was different, as it was a large exchange rate announcement that also came with a 50 basis point cut in the policy rate as well as large information effects. It is thus hard to know how much of the appreciation (USD/CHF changed by -10.8%) was due to the exchange rate announcement, an unrelated depreciation of the dollar, or any information effects. Our identification scheme is able to control for those and identify a smaller shock of -8.3%. To understand why that is the case, it is useful to look at an example of a monetary-driven

Figure 2: USD/CHF shocks



Notes: USD/CHF movements on SNB announcement days. Positive shocks reflect a CHF depreciation. The purged series consists of the residual from regressing the USD/CHF movements on monetary policy shocks, information effect shocks, and the NEER USD (specification 2). The two series displayed have a correlation coefficient of 0.84.

announcement with little information effects. For instance, the emergency 100 basis point rate cut of November 2008 related to the global financial crisis, which was a large monetary surprise that came with the announcements of a "generous and flexible" supply of liquidity. Did that announcement make the Swiss franc appreciate or depreciate? We observe that the Swiss franc depreciated against the dollar (1.1%), but this is mostly due to the unrelated appreciation of the dollar of about 1% that day (in NEER terms) as well as the rates cut (which tends to make the domestic currency depreciate). As such our identification scheme controls for those depreciating effects and reverses the sign to identify a shock of -0.7%, that is an appreciation of the Swiss franc. Such an appreciation is much more plausible given the large safe haven effects that Switzerland attracted during that period. The converse effect can be seen in the first post-COVID hike of June 2022, which was a large positive surprise (Swiss franc appreciated by 3.1% against the dollar) that is attenuated by our identification scheme (2.2%) due to the hike

and a depreciation of the dollar.

Once all of these factors are controlled for, our purged shocks z_t capture Swiss franc movements that are due to the SNB communication on the exchange rate, which we regard as exchange rate shocks. The results detailed in Section 4 therefore isolate the footprint of a purely domestic currency shock to the Swiss franc. Unsurprisingly, all of these results are invariant to instead using the simpler observed series ΔUSDCHF_t and adding the controls directly in the specification.[17]

3.2. Robustness to contamination

Does the estimation procedure correctly eliminate macroeconomic news caused by monetary policy announcement, and are they contaminated by unrelated macroeconomic events from the same day? We perform several robustness checks to ensure contamination is minimal, which we describe in details in Online Appendix C.

First we show that the purged shocks have very little to no predictive power for the stock returns of domestically-oriented firms. We estimate local projections of asset returns on our purged shocks and show that the reaction on impact of firms with less than 20% of their sales being in a foreign country is about 2.9 times smaller in magnitude than that of firms with 20-50% of foreign sales, with no significant reaction 5 days after the shock unlike more international firms. Similarly, more domestic sectors such as energy (no significant reaction at any horizon) or real estate (much lower in magnitude than other sectors and no significant reaction at horizons beyond 5 days) barely react to the purged shocks. If our shocks contained macroeconomic news about Switzerland, one would expect domestic firms to react to them. Similarly, we show that they have close to no predictive power for U.S. stock and gold prices with no significant response at any horizon, eliminating the possibility that they contain international macroeconomic news.

Second, we show that the exchange rate shocks have no predictive power for the expected path of domestic monetary policy three quarters ahead, as measured by futures by Koeniger et al. (2022). The purged shock have no significant relation to the expected path of monetary policy (with an R^2 of practically zero when regressed alone), both with and without controlling for the contemporaneous monetary policy shock and information effects. Again, if they were

[17] See Online Appendix F.

to be contaminated by current macroeconomic events, they would predict the expected path of policy even when we control for the contemporaneous monetary surprise. This further indicates that they are orthogonal to macroeconomic news not captured by our monetary and information shocks.

Lastly, we run all of our results with a narrow-window estimate of the exchange rate differential computed by Boneva et al. (2026) from 2004 onwards, which measures exchange rate movements between the SNB press release and end of press conference.[18] Such a narrow window eliminates all potential for foreign exchange rate news but not the concern that the exchange rate might reflect co-movement with the policy surprise or central bank information effects. We thus run the same purging scheme (without the need to control for the NEER) on these estimates and show that our results are qualitatively unchanged, though slightly lower in magnitude, to this alternative identification method.

It is important to note that we nevertheless keep the purged daily change in the exchange rate for our baseline results, as opposed to the purged narrow-window change. The reason is due to our asset prices being measured as daily variations, instead of narrow-window variations that would be extremely costly to acquire. Using the narrow series introduces a mismatch between the frequency of our shock and our daily price series. A simple check is to verify that the law of one price holds within our specification, which is highly likely given the low barriers to arbitrage in Swiss and American markets. This simple check fails under the mismatched windows but succeed under our baseline, despite the mismatch of the American and Swiss trading days.

4. Response of asset prices to the exchange rate

Our shock series permits us to estimate the causal effects of a change in the exchange rate. We trace the effect of an exchange rate shock on domestic asset prices via local projections (see Jordà, 2005). The corresponding price response of asset k on day $t+h$ since the SNB announcement day t is obtained by regressing the cumulative asset returns $\Delta p_{k,t+h} = 100(p_{k,t+h}/p_{k,t-1}-1)$

[18] Their measurement does not cover the 2011 EUR/CHF floor announcement since it was not a planned press conference: we estimate it to be 7.89% as a 20 minute window before and after the press release using Bloomberg data, and add it to the dataset.

against the exchange rate shocks:

$$\Delta p_{k,t+h} = \alpha_{k,h} + \beta_{k,h} z_t + \Gamma'_{k,h} X_{t+h} + \epsilon_{k,t+h}\,, \tag{3}$$

where z_t is the shock on announcement day t (detailed in Section 3) and X_{t+h} is a vector of controls that contains the post-shock cumulative USD nominal effective exchange rate (ΔNEER_{t+h}, $h \geq 1$) and domestic exchange rate movements ($\Delta\text{USDCHF}_{t+h}$, $h \geq 1$). The footprint of a given exchange rate shock on asset prices is then readily obtained by plotting the estimates $\hat{\beta}_{k,h}$ and their respective confidence intervals for up to $H = 60$ business days. This estimate measures the cumulated response to the exchange rate innovation, holding the subsequent exchange rate path fixed.[19]

4.1. Data on asset prices and cross-listings

Our sample period runs from January 2000 to December 2022, matching the SNB monetary policy regime that was adopted in 2000. If not mentioned otherwise, the data come from Refintiv Datastream. We use daily closing prices. The domestic listings of Swiss assets are in Swiss francs, while the corresponding US listings, if they exist, are in US dollars.

We capture all of the 212 free-floating stocks commonly traded as part of the Swiss Performance Index (SPI), the broadest Swiss stock index. In addition to prices, we use data on the economic sectors, market capitalization, and the currency denomination of sales which come from the firms financial statements reported in December 2022 (via Refinitiv Datastream). Firms that export more are also more likely to have a higher proportion of their cash flows in a foreign currency. We thus use the proportion of foreign sales (namely, the ratio of sales realized in foreign countries over total sales) as a proxy for foreign-denominated cash flows since the latter is typically not reported by firms.[20]

Importantly, the cross-listing of some stocks allows us to conduct the difference-in-differences identification presented in section 5. Among the 212 Swiss stocks, 54 are cross-listed[21] in the

[19]We do not control for liquidity in our regressions since the considered assets are typically often traded.

[20]While this does not hold true in all cases, such as for firms that invoice exporting goods in the domestic currency as in Auer et al. (2021), this proxy works well on average since foreign sales are a prerequisite for foreign-denominated cash flows. Given that we are interested in the direction rather than the exact magnitude of our estimated responses, this proxy should yield an adequate representation of the effect of foreign-denominated cash flows.

[21]The terms dual-listing and dually listed stocks are also used similarly in the literature to describe cross-listed

US via ADRs, which gives investors ownership in a foreign-listed firm.

Last, we extend our analysis to other asset classes focusing on bonds and gold. We use the S&P Switzerland Investment Grade Corporate Bond Index and the S&P Swiss Sovereign Bond Index for bond prices, which cover the main Swiss bond issuers and maturities. These bonds do not have foreign listings. For gold, we use the price per kilogram of 995-purity bars, as measured by UBS in Zurich. The immediate equivalent US listing is the price of the same gold bars in US dollars measured by Handy & Harman, which we convert from ounces to kilograms.[22]

Working with cross-listed stocks requires careful attention to timing issues between the domestic assets, foreign assets, and exchange rate measurements. We illustrate those timing differentials in Appendix Figure A8. Using Swiss time (up to some daylight savings differences), the Swiss market opens between 9:30 and 17:30 while the American market opens from 15:30 to 22:00.[23] The exchange rate is measured ever hour, which allows us to take the difference between 17:00 fixings and approximately match the Swiss stock market. As such, the daily change in asset prices reflect news from 17:30 in $t-1$ to 17:30 in t for Swiss assets, and from 22:00 in $t-1$ to 22:00 in t for American ones. This is not an issue for our identified shocks to have an effect, since monetary policy announcements are typically made around 9:30 or 10:00 and would thus be captured by the daily change in all three markets. One issue would be if asset prices faced movements between the Swiss and US fixing times that were systematically correlated with our exchange rate shocks. Such movements between 17:30 and 22:00 would be accounted for at t for the US price but at $t+1$ for the domestic price. Importantly, we do not find evidence of such movements between the fixing times.[24]

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firms.

[22]The standard USD gold price is that measured by LBMA with a fixing at 4 p.m. London time, which matches well with the Swiss stock market hours. We instead use the less standard New York Handy & Harman fixing to match the ADR data that are also fixed at New York time. That way, the results for stocks and gold are comparable.

[23]The exact fixing time depends on the asset and whether it is traded over-the-counter or as part of a larger exchange, but the vast majority are fixed at 4 p.m. or 5 p.m. New York time

[24]We cannot test this directly for stocks without intraday data. However, we can test it for gold using closing prices in multiple locations. We thus ran the regressions involving gold (shown in Section 4) twice, with the London and New York fixings. The results for gold are extremely robust to the change in fixing, hinting that the fixing time difference should not be a concern. Further evidence that the timing window difference is inconsequential is that the law of one price holds in our sample as we explain later and show in Figure 4, while it would not hold should there be significant correlated events in that window. This further shows why we must use daily exchange rate movements: using a narrower window introduces a mismatch that wrongfully makes the law of one price appear to fail, as we have shown previously in section 3.

4.2. Response to exchange rate shocks

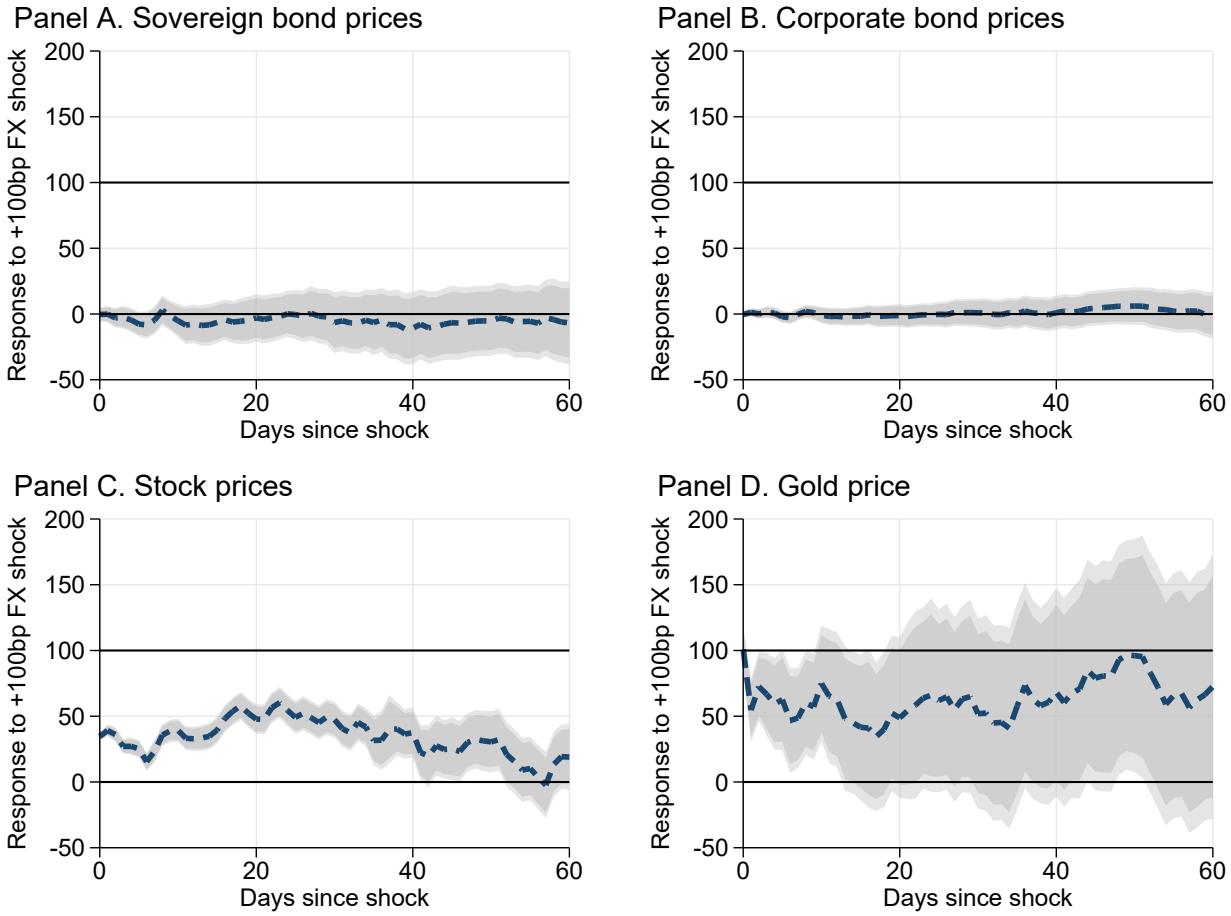
Figure 3 plots the asset price responses to a 100 bp USD/CHF shock (that is, a Swiss franc depreciation) using local projections. While the plots are shown in response to a depreciation, we of course use both appreciations and depreciations to compute those estimates, since we find their effects to be symmetric. According to our estimates, a currency depreciation has no significant effect on bond prices, either sovereign or corporate.[25] In contrast, the depreciation immediately and persistently increases stock and gold prices. On impact, the price of both asset classes increases by approximately 35 bp and 101 bp, respectively. The effect then persists over the next 60 days, reaching an average effect of 34 bp and 63 bp over the time horizon considered. Conversely, a domestic currency appreciation decreases gold and stock prices but has no significant effect on bond prices, as was highlighted by the large appreciation shock of January 2015 shown in Figure 1. Overall, the effect of exchange rate shocks on domestic asset classes supports the law of one price considerations that are discussed in Section 2.

The marked differences in price responses across asset classes highlights the role played by currency denomination. In this regard, the gold and bond price responses provide boundary cases for stocks. On the one end of the spectrum, bond prices do not respond because bonds deliver cash flows that are entirely denominated in Swiss francs. The cash flows of the asset remain unaffected by the exchange rate movement, and there is thus no reason for the valuation of domestic bonds to adjust.[26] Swiss bonds are not cross-listed in the US. Accordingly, the law of one price manifests itself simply via exchange rate movement: an investor who operates in US dollars faces a mechanically higher price when purchasing the domestic bond and translating it into US dollars. On the other end of the spectrum, gold displays the sharpest price response because it does not deliver monetary cash flows but is priced at multiple locations simultaneously. The price of gold in Switzerland must therefore be equal to the price of gold in the US converted to Swiss francs. Because Swiss franc shocks have little implications for the worldwide gold market, any arbitrage opportunities are cleared via the adjustment in the domestic Swiss price. A Swiss franc depreciation thus forces the Swiss price of gold to increase

[25]The absence of a response from corporate bonds provides evidence that the exchange rate shocks do not affect the creditworthiness of corporate bond debtors in Switzerland.

[26]Naturally, bond prices adjust to the unexpected interest rate movements that take place on SNB announcement days. This effect is captured by the control for interest rate shocks, which directly affect bond prices at all maturities (see Koeniger et al., 2022), not by exchange rate shocks.

Figure 3: Response of domestic asset prices to a 100 basis point Swiss franc depreciation



Notes: Responses in basis points to a purged USD/CHF shock of +100 basis points (CHF depreciation). Using specification 3, 90% (95%) confidence intervals in dark (light) grey area. Stock price responses use pooled regressions with the individual stocks. All prices are in CHF and traded in Switzerland. Corresponding regression results are displayed in the Online Appendix Table A5.

almost one-to-one to maintain price parity. The response of stocks lies between the boundary cases provided by bonds and gold. As a real asset, a stock provides monetary cash flows that depend on the exchange rate, in turn affecting the asset valuation. This is depicted in the empirical responses shown in Figure 3.

Price parity should strictly hold for assets that are perfectly substitutable, such as cross-listed stocks or gold. This is the case in our data, which we interpret as both supporting evidence for the currency denomination mechanism and as a quality check (see Online Appendix Figure A7 for two individual examples over all trading days). We assess this by running pooled local projections on the difference in currency returns for each of the 54 cross-listed stocks (as well

as for gold):

$$\Delta p^{CH}_{i,t+h} - \Delta p^{US}_{i,t+h} = \alpha_h + \beta_h z_t + \Gamma'_h X_{t+h} + \epsilon_{i,t+h}\,, \tag{4}$$

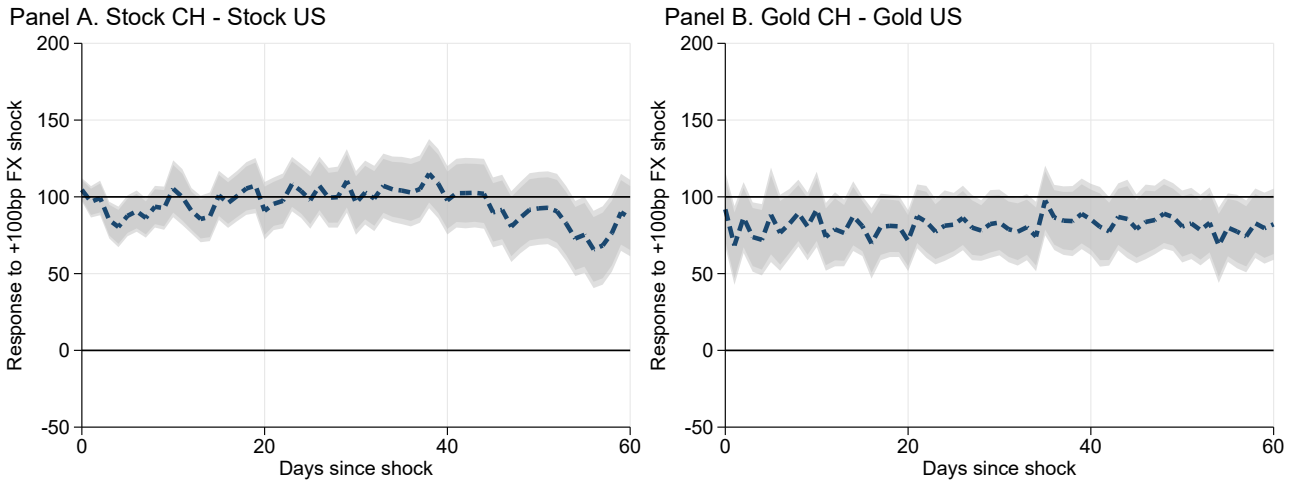
which uses the same controls X_{t+h} as in specification 3 and in which $p^{US}_{i,t+h}$ denotes the ADR price of stock i in the US. Price parity is strictly respected when β_h is equal to one over the time window considered as arbitrage opportunities would arise otherwise. This is illustrated in Figure 4, which reveals a strictly enforced price parity for both cross-listed stocks and gold over the 60 days that follow the exchange rate shocks. If anything, our estimation of price parity is marginally affected by specific stocks with very low liquidity, for which differences can arise. However, only 3 or 4 stocks display such large jumps, so that they do not significantly impact our pooled results.[27] We therefore do not find evidence of profitable arbitrages for cross-listed Swiss firms, which is in line with the existing evidence on cross-listing.[28]

We contribute to the literature by identifying the mechanism that drives the response of stock prices to the exchange rate. In Section 2, we presented two mechanisms that can explain this reaction, namely the *economic conditions* and *currency denomination* hypotheses. Although the empirical reaction of stocks that we find is consistent with both hypotheses, its economic interpretation differs. The cash flows of several Swiss stocks are denominated in foreign currencies before being converted into Swiss francs. Accordingly, a Swiss franc depreciation increases the (current and expected) cash flows expressed in Swiss francs, which makes the firm relatively more profitable. When instead thinking in terms of *economic conditions*, the depreciation makes it cheaper to export Swiss products, in turn pushing up aggregate demand in the domestic country. By examining the response of the individual stocks in the next section, we provide supporting evidence that the *currency denomination* mechanism dominates and thus drives how stock prices react to the exchange rate.

[27] See Online Appendix Figure A7 for an extreme example of a low-volume stock compared to a high-volume stock. In that case, the foreign listing price moves periodically in large jumps when the difference with the domestic price grows too large, showing realized arbitrage opportunities.

[28] Using intra-day ADR data on cross-listed stocks from different countries, Gagnon and Karolyi (2010) also report minor deviations from the law of one price. The deviations are correlated with measures that reflect frictions (such as holding and transaction costs as well as foreign investment restrictions). The role of frictions is also documented in Fung et al. (2022), who show that a flexible exchange rate regime enforces better the price parity of cross-listed Chinese stocks. Similarly, Rosenthal and Young (1990) find no profitable trading rules for two firms that are listed in the US and the UK. Although De Jong et al. (2009) find some evidence of abnormal returns for cross-listed firms, it is accompanied by large volatility and negative returns, in turn jeopardizing arbitrage.

Figure 4: Response of difference in currency returns to an exchange rate shock



Notes: Responses in basis points to a purged USD/CHF shock of +100 basis points (CHF depreciation). Using specification 3, 90% (95%) confidence intervals in dark (light) grey area. Stock price responses use pooled regressions with the individual stocks. Corresponding regression results are displayed in the Online Appendix Table A7.

5. Causal evidence on the currency denomination effect

While it is clear that international parity adjustments drive the stark response of commodity prices to the exchange rate, it is far less evident which of the two channels dominates for stocks. We thus provide a lower bound to the size of the *currency denomination* channel for stocks by using the idiosyncratic introduction of cross-listings.

Cross-listing is a stringent case of international substitution because it provides a perfect foreign substitute to a domestic asset. Absent marked frictions (such as large transaction costs), exchange rate movements should be perfectly compensated by changes in the listings' prices at home and abroad. The additional sensitivity to exchange rate movements provided by a cross-listing is only part of the full currency denomination channel, however, since we would expect some degree of substitution to other stocks even if no cross-listing were available. We thus argue that our estimates, while sizeable, are only a lower bound to the effect.

For Swiss companies, cross-listing on the American market is carried through American Depostary Receipts (ADRs). These financial products are often used by non-US companies to be listed in the US without having to undergo a costly public offering or comply with reporting standards. ADRs are issued by commercial banks and are then traded on the New York Stock Exchange (NYSE), the Nasdaq stock exchange or over-the-counter. Both the ADR price and

dividends are denominated in USD, which makes it easier for American-based and international investors to access foreign stocks (see Alexander et al., 1987 for a discussion on how cross-listing removes trading frictions). An ADR can be converted into its underlying domestic stock and vice-versa. Applying the exchange rate, any price deviation between the two listings can thus be arbitraged to make a riskless immediate profit. In line with this, price parity between cross-listed Swiss stocks and their US listings holds in our data.[29]

In practice, the presence of an ADR makes it easier for USD-denominated investors to trade the stock. Thanks to the ADR, foreign investors no longer need to convert the domestic stock price into foreign currency and can operate at their usual trading time. Cross-listing thus reduces trading frictions, in turn making it easier for USD-denominated investors to compare the ADR prices to other USD-denominated substitutable stocks (for instance, the Novartis ADR versus the Pfizer stock). To remain comparable with other USD-denominated substitutable stocks, ADR prices can only react to some extent to the domestic exchange rate. By the law of one price, the response of the domestic stock prices of cross-listed firms is accordingly enhanced (as discussed in Section 2). An ADR can be converted into the underlying domestic stock and vice-versa; arbitrage opportunities would thus arise from any price deviations. This mechanism is akin to the previously discussed case of gold: a shock to the Swiss franc will be reflected in the Swiss price of gold to respect parity with the global USD quotation.

We exploit cross-listing to provide causal evidence of the degree of substitution that is due to currency denomination. To do so, we exploit the staggered introduction of ADRs with a synthetic difference-in-differences approach. We analyze ADRs since they are by far the most frequent cross-listing vehicle for Swiss stocks, but our findings should hold for any type of cross-listing.[30] We show that the introduction of an ADR amplifies domestic stock returns by exacerbating their reaction to exchange rate shocks. The effect is sizeable: approximately one-third of the Swiss stock price movements that follow exchange rate shocks are attributed to cross-listing.

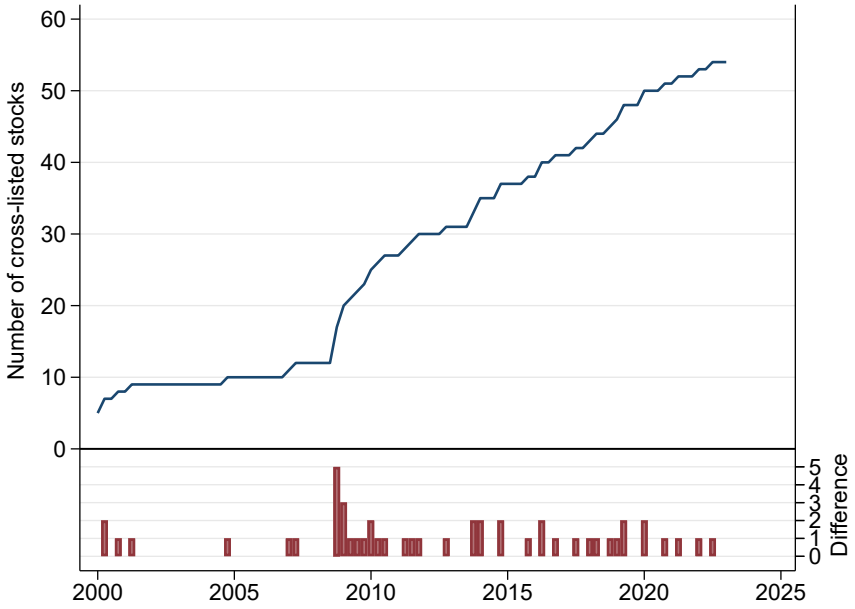
[29]Lamont and Thaler (2002) observe that the law of one price does not always hold in the ADR stock market. The reasons for the ADR discrepancies include high transaction fees, illiquidity, large dividend payments, as well as the US macroeconomic and consumer sentiment Grossmann et al. (2007).

[30]This includes listings on non-US markets via global depositary receipts (GDRs) and direct foreign listings. For Switzerland however, these cases are marginal and ADRs are much more prevalent than any other cross-listing vehicle.

5.1. Identification via synthetic difference-in-differences

Our identification strategy relies on the staggered introduction of foreign listings in Switzerland. Throughout the sample period, Switzerland went from having only 5 firms[31] listed in the US in 2000 to 54 in 2022, all of which took place via the issuance of ADRs. In line with the causal inference literature, we refer to the introduction of an ADR as a *treatment* for the domestic stock. We use the first day of trading of the ADR as the treatment day, which is typically the day following SEC approval and first announcement of the cross-listing.[32] ADR introductions provide adequate treatment variations. They were spread over time, with approximately one new listing per quarter (see Figure 5). The listings are thus well scattered around the exchange rate shocks that take place on (the typically quarterly) SNB announcement days.

Figure 5: Introductions of American Depositary Receipts (ADR) for Swiss stocks



Notes: Quarterly difference. Total of 212 Swiss-listed firms; see Section 4.1 for details on cross-listing.

Our identification is based on the difference-in-differences (DID) framework to address the fact that the firm's decision to be cross-listed is not random. The endogeneity issue that would

[31]Namely Credit Suisse, Logitech, Nestlé, Roche and Swisscom.

[32]Some firms may decide to announce their intent to introduce an ADR before SEC approval. For instance, ABB announced their intent on March 20, got approved on April 5, and started trading on April 6. This is not a concern for our regression as long as theses announcements do not predate the previous SNB meeting day too often, which are quarterly. We importantly find strongly parallel pre-trends before the first trading day, as reported in section 5.3 and which indicates little pre-introduction information leakage at the quarterly level.

bias a standard linear regression lies in the fact that Swiss stocks also listed in the US are systematically different from stocks that are solely listed domestically. Directly comparing stocks with and without an ADR would thus yield biased results. Among other factors, foreign firms cross-listed in the US display higher valuation levels (Doidge et al., 2004) and a higher investment-to-price sensitivity (Fresard and Foucault, 2012). In line with this, Table 1 reports binary regressions on the probability that a given Swiss firm is cross-listed. Independent of their sector, cross-listed firms are significantly larger and have greater international exposure, as measured via market capitalization and the foreign sales ratio. They also tend to be in more international sectors such as tourism, biotech and medical or banking. By taking this into account, our DID identifies the impact of cross-listing (the *treatment*) on domestic stock returns. The DID uses the non-treated stocks as a control group that provides an imperfect counterfactual for the treated stocks. The key assumption for the DID to correctly estimate the treatment effect is that stock prices would have followed parallel trends without the treatment. This would typically be violated if the exact timing of the ADR introduction was endogenous, i.e. if some key event would trigger the introduction of an ADR. For instance, it would be possible that firms decide to introduce a cross-listing when their domestic stock returns are at their highest, the effect of which would be confounded by the treatment. We argue this is unlikely given the relative legal complexity to introducing ADRs and the likely delay between this decision and the actual introduction of the cross-listing, and decide to further relax our reliance to that assumption through our methodology.

Given potential concerns about the exact treatment timing being endogenous, we partially relax the parallel-trend assumption by using a synthetic difference-in-differences (SDID) approach. SDID follows a long line of work on synthetic controls; Arkhangelsky et al. (2021) showed its appealing features. SDID optimally weights each unit of the control group to mimic the FX-sensitivity of the treated group. The resulting synthetic control group, which replicates the price of the treated stocks before the treatment, provides an adequate counterfactual and mechanically creates more parallel trends (see section 5.3 that shows these synthetic pre-trends). This introduction timing issue is similar to the setting of Bilicka (2019), which uses propensity score matching to compare similar international firms. The synthetic approach is similar to theirs in spirit: we place larger weights on firms whose asset returns are similar before the treatment, such that we avoid the possibility of comparing firms with temporarily exceptional

Table 1: Probability of a firm being cross-listed in the US

	Baseline		With sectors	
	Probit	Logit	Probit	Logit
Log market capitalization	0.41***	0.75***	0.44***	0.84***
	(0.07)	(0.14)	(0.08)	(0.17)
Foreign sales ratio	1.21***	2.04***	1.27***	2.29***
	(0.38)	(0.70)	(0.47)	(0.88)
Dividend yield	0.08	0.19^{+}	0.11	0.27^{+}
	(0.07)	(0.12)	(0.09)	(0.16)
Constant	-4.60***	-8.42***	-4.37***	-8.60***
	(0.63)	(1.31)	(0.92)	(1.85)
Sectoral dummies	No	No	Yes	Yes
Pharmaceutical			(base level)	
Bank			1.38^{+}	2.45^{+}
Biotech and medical			1.25^{+}	2.35*
Industrial			0.63	1.26
Insurance and financials			0.61	1.08
Real estate			0.61	1.25
Retail			0.75	1.44
Services			0.64	1.06
Technology			0.82	1.44
Tourism			2.48**	4.68***

Notes: Probit and Logit regressions on $Pr(ADR_i = 1)$, namely the probability that a firm i is dually-listed in the US by the end of the sample period (in 2022). Significance levels: $+\ p < 0.20$, $*\ p < 0.10$, $**\ p < 0.05$, $***\ p < 0.01$. Standard errors in brackets.

profits to ordinary firms. Even if a bias were still present, we would most likely underestimate the effect of the introduction of ADR since it is unlikely that the post and pre-treatment effects (if they even exist) go in opposite directions, which would not be a threat to the validity of our lower-bound estimates.

Thanks to its weighting system, SDID also solves the recent heterogeneous treatment effect and forbidden comparisons issues of two-way fixed effects (TWFE) estimators highlighted in De Chaisemartin and d'Haultfoeuille (2020), Goodman-Bacon (2021), or Baker et al. (2022). By addressing these issues and improving the comparability of the control group, SDID provides a more adequate approach to assessing the effects of cross-listing than those alternative TWFE estimators. The SDID estimator is also able to address the issue of staggered treatment adoption

because it is repeated for every adoption date.[33]

We follow the methodology of Arkhangelsky et al. (2021) to compute our SDID estimates. The unit weights of the synthetic control group $\hat{\omega}_{i,h}$ are computed such that the resulting control group is as parallel as possible to the treated group before the treatment. The time weights of the SNB announcement days $\hat{\lambda}_{t,h}$ are computed such that the pre- and post-treatment exposures are balanced, which reduces the impact of extreme shocks. Online Appendix B details the two minimization problems that compute these weights. Finally, a weighted TWFE estimates the treatment effect by minimizing the weighted residuals:

$$\left\{\hat{\mu}_h, \hat{\gamma}_h, \hat{\delta}_h, \hat{\beta}_h\right\}_{h\in H} = \arg\min_{\mu,\beta,\gamma,\delta} \sum_{i\in I}\sum_{t\in M} \left(\Delta p_{i,t+h} - \mu - \gamma_i - \delta_t - \text{treat}_{it}\beta\right) \hat{\omega}_{i,h}\hat{\lambda}_{t,h}\,, \tag{5}$$

where $\hat{\beta}_h$ is the average treatment effect on the treated (ATET) for stock returns h days after a given SNB announcement. As in the standard DID, the TWFE includes a constant μ_h, time and unit fixed effects $\gamma_{i,h}, \delta_{t,h}$ and a treatment dummy $\text{treat}_{it} \in \{0, 1\}$. For the sake of comparison, we also report the standard DID estimates, which are computed via the same TWFE without the weights $\hat{\omega}_{i,h}, \hat{\lambda}_{t,h}$.

The standard errors of both the DID and SDID are computed using a clustered bootstrap. Arkhangelsky et al. (2021) propose three approaches for variance estimation in SDID: bootstrap, jackknife, and placebo. Although the placebo approach is the most computationally efficient, it is better designed for a small number of treated units. Because we have a large number of treated stocks and time periods, bootstrap and jackknife estimations are better suited. We choose bootstrapping since it is the most common and well-known estimator, is straightforward to implement in both the DID and SDID, and yields robust performance in the experiments of Arkhangelsky et al. (2021).

Assessing the causal effect of cross-listing via synthetic DID requires us to divide the sample according to the direction and persistence of the exchange rate shock. That is first because of pooling issues, since estimating a single average treatment effect cannot directly accommodate effects going in opposite directions. In particular, the currency denomination hypothesis pre-

[33]See the staggered-adoption appendix of Arkhangelsky et al. (2021) for a more detailed description.

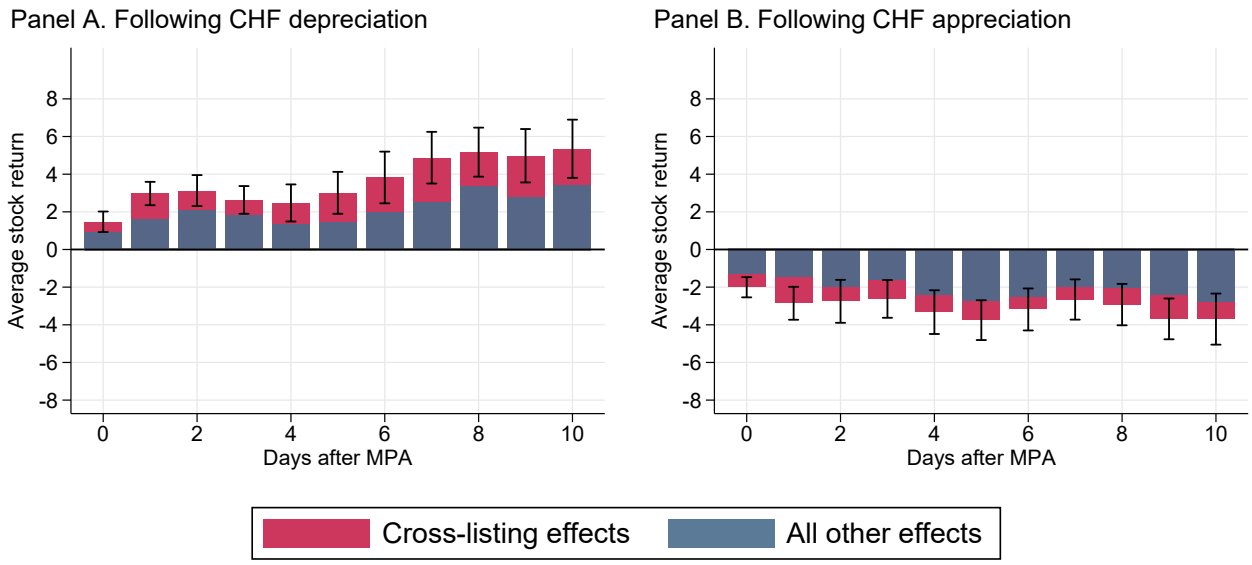
dicts a positive stock return after a depreciation (that is, a positive exchange rate shock) and a negative return after an appreciation (a negative shock) so that the average treatment effect has opposite signs in the two cases. Estimating all shocks jointly would therefore yield a null if the positive and negative exchange rate shocks were balanced. Similarly, using the absolute stock market returns would also mischaracterize the ATET since not all stock price responses may have the same sign. A straightforward solution is to instead run the estimation twice: first for the effect of ADR introduction on the stock returns that follow *positive* exchange rate shocks and second for the effect on stock returns that follow *negative* exchange rate shocks. A second concern is that of inference: our shock series is noisy and contain many small shocks that may not carry significant exchange rate information. We thus restrict our subsample not only on the sign of the shocks but on their size by selecting only movements in the Swiss franc that persist in sign in the days following the monetary policy announcement.[34] This selection yields two subsamples of 30 balanced and large shocks (16 positive and 14 negative).

5.2. The causal effect of cross-listing on stock prices

Our identification reveals that cross-listing has a sizeable causal effect on the sensitivity of domestic stock prices to exchange rate shocks. The corresponding estimates are reported in Table 2. The DID and SDID ATET estimate the effect of an ADR introduction on its respective stock returns (in percentage points). Our results are more easily interpreted when converting the coefficients into how cross-listing contributes to the sensitivity of domestic stock returns to exchange rate shocks. To do so, we divide the estimated contribution of cross-listing by the average stock return for the treated firms. The resulting cross-listing contribution is computed from the SDID ATET since it is robust to staggered and heterogeneous treatments and relies on relatively weaker assumptions. Using the first row of Table 2 as an example, the average domestic stock return of 1.47% on announcement days with a positive exchange rate shock (that is, a depreciation), together with an ATET of 0.55, gives a cross-listing contribution of $0.55/1.47 = 37\%$. Figure 6 plots the corresponding cross-listing contributions of Table 2 over

[34] We use $\Delta USDCHF_{t+h} - \Delta NEER_{t+h}$ up to $H = 15$ days after the monetary policy announcements to determine whether the shock was positive or negative. By doing so, we only keep the Swiss franc part of the bilateral exchange rate USD/CHF. We use the cumulative exchange rate shock up to 15 days after the monetary policy announcement to only keep the shocks that are clearly positive or negative. That is, the shocks that are positive or negative on impact and are not reverted in the following 15 days.

Figure 6: Effect of cross-listing on cumulated stock market returns



Notes: Cumulative average domestic stock return for cross-listed firms conditional on direction of exchange rate movement following the SNB announcement. Whiskers indicate 95% confidence intervals of the cross-listing contribution computed in Table 2. All other effects is the difference between the average stock return and the cross-listing contribution.

the 10 days that follow SNB announcements.

Cross-listing meaningfully affects the response of stock prices to the exchange rate shocks. Table 2 and Figure 6 show that the SDID coefficients and corresponding contributions are significant. The contribution of cross-listing is overall symmetric for positive and negative exchange rate shocks. On SNB announcement days, more than one-third of the average stock return that followed a positive exchange rate shock is due to the presence of cross-listing. For returns that followed the negative shocks, we obtain a similar contribution of 36%. By increasing the stocks' degree of substitution across denominations, cross-listing causes much of the variation in stock prices in Swiss francs that is observed following exchange rate shocks. By a mirror effect of the law of one price, cross-listing reduces the effect of exchange rate shocks on the dollar price of Swiss companies.

The effect of cross-listing on domestic stock returns is not only sizeable but also lasting. The SDID estimates are significant regardless of the time horizon h considered. In the 10 days that follow SNB announcements, the effect of cross-listing on stock market returns ranges between 30% and 51% for returns that follow positive shocks (41% on average). Following negative shocks, the contribution is between 20% and 49% (31% on average). These results are thus

Table 2: Effect of cross-listing on cumulated stock market returns

	Positive FX shocks (CHF depreciation)				Negative FX shocks (CHF appreciation)			
Days after MPA (h)	Average return	DID ATET	SDID ATET	Cross-listing contribution	Average return	DID ATET	SDID ATET	Cross-listing contribution
0	1.47	0.68**	0.55**	0.37	-2.01	-0.69**	-0.73***	0.36
		(0.30)	(0.28)			(0.29)	(0.27)	
1	2.97	1.25***	1.36***	0.46	-2.86	-1.34***	-1.40***	0.49
		(0.32)	(0.32)			(0.42)	(0.45)	
2	3.13	1.60***	1.05**	0.34	-2.75	-0.55	-0.77^{+}	0.28
		(0.46)	(0.42)			(0.46)	(0.58)	
3	2.63	1.11***	0.80**	0.3	-2.63	-0.73^{+}	-1.02**	0.39
		(0.41)	(0.38)			(0.48)	(0.51)	
4	2.47	0.98**	1.09**	0.44	-3.33	-0.99*	-0.90^{+}	0.27
		(0.48)	(0.50)			(0.59)	(0.59)	
5	3.01	1.15*	1.54***	0.51	-3.75	-0.72^{+}	-1.04*	0.28
		(0.65)	(0.57)			(0.55)	(0.54)	
10	5.35	1.62*	1.94**	0.36	-3.70	-0.62	-0.91^{+}	0.25
		(0.92)	(0.79)			(0.74)	(0.69)	
15	6.62	1.26	1.85*	0.28	-2.36	-0.61	-1.62**	0.69
		(1.24)	(1.06)			(0.73)	(0.71)	
20	2.69	-2.69*	0.18	0.07	-1.01	-1.03^{+}	-0.33	0.33
		(1.45)	(1.17)			(0.72)	(0.77)	
30	6.01	-0.36	2.81*	0.47	0.23	0.86	0.93	3.97
		(1.73)	(1.45)			(1.03)	(1.24)	
40	8.20	0.44	3.51**	0.43	1.79	-2.32^{+}	-4.75	-2.65
		(1.91)	(1.58)			(1.64)	(4.56)	

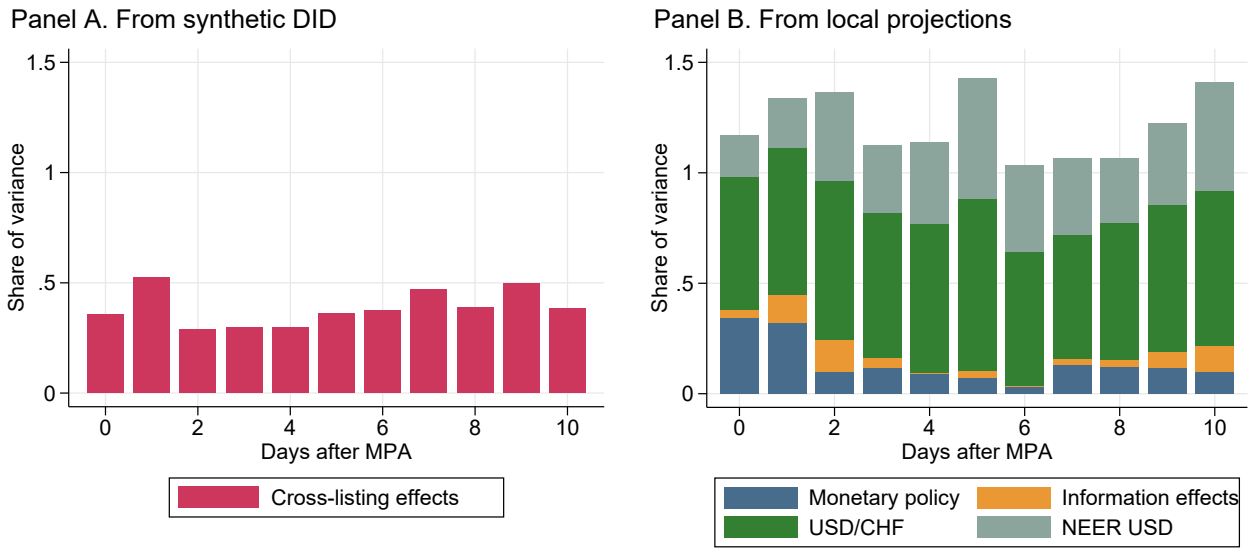
Notes: Using specification 5. Average treatment effects on the treated (ATET) and average stock return on the treated. Cross-listing contributions are the ratio of the SDID ATET over the average return on the treated. Significance levels: $+\ p < 0.20$, $*\ p < 0.10$, $**\ p < 0.05$, $***\ p < 0.01$. Bootstrap standard errors (with 100 replications) in brackets.

rather symmetric for positive and negative shocks, with a 10-day overall average of 36% that matches the cross-listing contribution on impact.

The effects of cross-listing are also large when compared to the effect of other fundamental shocks. This can be seen in Figure 7, which shows the proportion of the SPI returns' standard deviation for the various time horizons (h) since SNB announcements for both cross-listing and the monetary policy and information shocks that are used as controls throughout the paper and were described in Section 3. In Figure 7, the contribution of those shocks is obtained by dividing their respective local projection estimates[35] on the SPI returns' standard deviation at

[35]These are obtained via regressing $\Delta p_{t+h} = \alpha_h + \beta_{1,h}\Delta\text{NEER}_t + \beta_{2,h}\Delta\text{USDCHF}_t + \beta_{3,h}\text{MoPo}_t + \beta_{4,h}\text{Info}_t + \epsilon_{t+h}$.

Figure 7: Variance decomposition of Swiss stock returns



Notes: The cross-listing effect is the average of the cross-listing contributions in the two subsamples computed in Table 2. Panel A relates the SDID coefficients to the standard error of stock returns $\Delta p_{i,t+h}$ with: $\left|\hat{\beta}_h^{SDID}\right| / \sigma_{\Delta p_{i,t+h}}$. Panel B relates the local projection results to the relative standard deviation of each independent variable with $\sigma_{x_{j,h}}$: $\left|\hat{\beta}_{j,h}\right| \sigma_{x_{j,h}} / \sigma_{\Delta p_{i,t+h}}$, in which $\hat{\beta}_{j,h}$ is the coefficient obtained from the specification described in footnote 35 for the shock x_j. We show the absolute values of the coefficients for visual reasons.

time horizon h since the SNB announcements.

Cross-listing can explain more variations in domestic stock price movements on announcement days than the combined effect of monetary policy and information shocks. Figure 7 shows that in the 10 days that follow SNB announcements, approximately 14% of the average domestic stock returns can be attributed to monetary policy shocks, whereas just 6% is due to information shocks. [36] In comparison, approximately 39% of the average stock returns is due to cross-listing. While exchange rate movements are known to explain stock returns,[37] our causal evidence provides support for a *currency denomination* mechanism of sizeable magnitude that underlies the observed correlation.

As a corollary, cross-listing sizably *amplifies* domestic stock responses to exchange rate shocks. The issuance of ADR comes with a high degree of substitution between the corresponding domestic and foreign stocks. As a result, a depreciation of the domestic currency led

[36] Instead using the monetary policy surprises of Bu et al. (2021) yields a similar magnitude (see Online Appendix H).

[37] For instance, Dunne et al., 2010 use 800 million stock trades in the US and France to find that more than half of the daily returns of the SP100 can be explained by exchange rate movements and aggregate flow orders.

to a stronger rise in the domestic asset price and a smaller decline in the foreign asset price, so that the law of one price holds. Hau and Rey (2006) also find that a currency depreciation is associated with domestic stock returns that are relatively higher than the foreign returns.[38] In Hau and Rey (2004), portfolio rebalancing is found to be consistent with this relationship. While these results suggest that the exchange rate movements are related to stock market developments, we provide causal evidence via our exchange rate shocks for the Swiss franc. The announcement days that we use are associated with high exchange rate volatility, under which portfolio rebalancing tends to be more intense (Camanho et al., 2022 provide evidence at the fund level). Together with our use of staggered cross-listing introduction, we show that currency *denomination* can explain a sizeable part of the observed correlation (and thus a resulting portfolio rebalancing) on central-bank announcement days.

It is straightforward to extrapolate this sizeable amplification to the *overall* domestic stock market index. Although only 54 Swiss stocks out of 212 are cross-listed in the US, they make up the majority of the stock volume and thus almost single-handedly drive the Swiss stock indices. Consequently, the presence of cross-listing can explain approximately one-third of the Swiss stock index movements that follow exchange rate shocks.[39] This illustrates again that currency *denomination* plays an important role in stock price fluctuations that are due to the exchange rate.

5.3. Pre-trends, placebo test, and alternative specifications

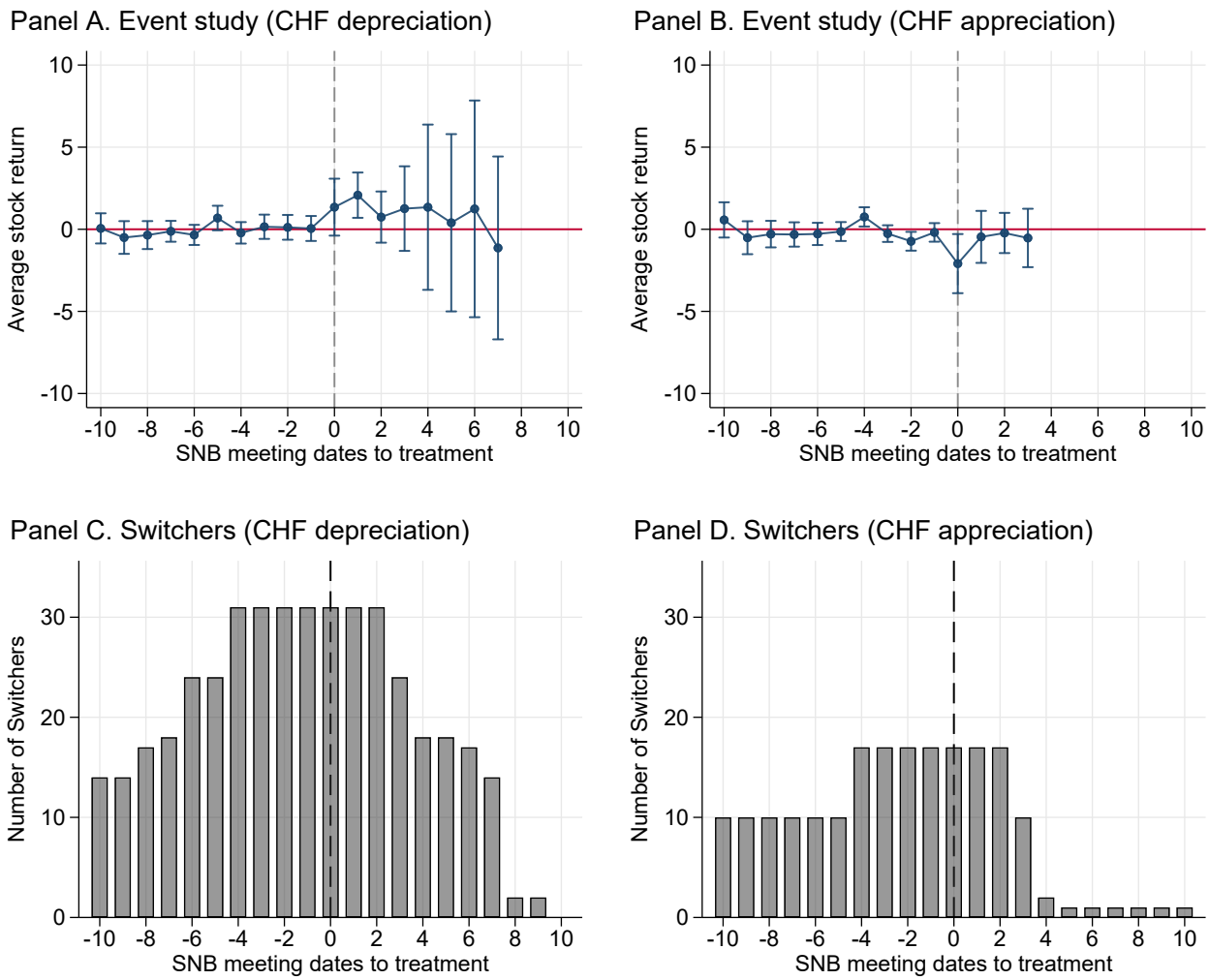
The key assumption that our identification scheme relies on is that, absent cross-listing, the returns of treated stocks would have evolved in parallel with those of the synthetic control group. We perform two checks to ensure that assumption is appropriate.

First we study pre-treatment dynamics. Figure 8 shows the 1-day-ahead SDID coefficient as an event study rather than a single treatment event. We only show coefficients for which a sufficient number of switchers (as shown in Panels C and D) are available. The pre-treatment

[38] They document the relationship for 17 countries (versus the US) at the daily, monthly and quarterly frequencies.

[39] At the end of 2022, 96% of the core Swiss stock market index (SMI) stocks and 81% of the broader index (SPI) stocks were cross-listed in the US. The two indices are weighted by market capitalization and rely heavily on a few large companies (such as Nestlé, Roche or Novartis).Consequently, the treatment is applied to 96% of the SMI and 81% of the SPI. Multiplying our ATET by these fractions, we find that at least 35% of SMI returns and 29% of SPI returns following exchange rate shocks can be explained by cross-listing effects. This result is a lower bound since there might be some spillover effects to untreated stocks, which we do not measure.

Figure 8: Event study around ADR introduction



Notes: SDID event study estimator for an horizon of 1-day after MPA. Whiskers indicate the 95% confidence interval computed with placebo standard errors (with 300 replications).

coefficients directly test whether the exchange rate sensitivity of treated stocks diverged before the ADR introduction. From Panel A we note no evidence of a pre-trend: none of the ten Swiss franc depreciation shocks before the introduction of an ADR carry a statistically significant coefficient, nor are they sizable. Panel B also indicates no sizable pre-trend but is more nuanced: two of the ten Swiss franc appreciation shocks before the introduction of an ADR carry statistical significance (one positive, one negative). Since their sign are opposite, their magnitude relatively small, and no overall trend appears in those pre-trends, we attribute them to randomness. Overall, the synthetic method appears to accurately match pre-trends, as could be expected.

A byproduct of this event study is also to be able to decompose our post-treatment coefficient through time. Doing so unfortunately loses a lot of power, as is usual with event studies, especially since the number of post-treatment switchers reduces quite dramatically after a few periods. Nevertheless, we observe that the treatment effect is mostly concentrated at impact, rejecting a slow gradual increase of FX senstitivity after the ADR introduction. In other words, the introduction of an ADR seem to immediately offer a foreign exchange substitute for the stock and hence has an immediate effect, as could be expected from theory.

Second, we test our estimation procedure with some placebo treatments. That is, we restrict our sample to never-treated units, randomly assign treatment to a subset of them (same size and treatment dates as our true treatments), and run our SDID regression for 1-day ahead returns. Any result obtained from such a regression is pure noise. We compare those draws to our baseline results in Online Appendix Figure A10, and find that only 1.7% of the placebo-treatment ATT are larger in magnitude than our CHF-appreciation result, and only 6.7% are larger than our CHF-depreciation result (most of which are of the opposite sign). This confirms that our inference is robust to the choice of method (placebo instead of bootstrap).

For completeness, we report a balance table of firm characteristics for the treated, control, and synthetic control groups in Online Appendix Figure A9. We already established that cross-listed firms differ systematically from single-listed ones, as documented in Table 1: they are larger, have higher shares of foreign sales, and are in particular sectors. Our synthetic control group does not target these characteristics, it solely weighs sensitivity to exchange rate shocks (the outcome). It is therefore informative to ask whether the outcome-based synthetic group also brings firm characteristics closer to the treatment group. This is the case overall: the synthetic group tends to weigh larger and more international firms more than the control group, even though it is still far from the treated group. This is to be expected since these firm characteristics are only noisy proxies of our outcome and exact balance is not required. Yet their direction is supportive of the synthetic control group weighting the right observations.

Lastly, we explore alternatives to our subsampling scheme. The main concern is that of subselecting a non-representative subset of only the largest and most persistent shocks, since we condition on the sign of the Swiss franc movement to persist after the announcement. Online Appendix D drops that assumption and reports estimates based on subsamples that are classified only by the sign of the exchange rate movement on the announcement day. This

retains all announcement days, including the smaller and noisier ones that may convey very little meaningful exchange rate information. Our results are nevertheless qualitatively robust to that scheme, in that the sign of the coefficients largely match that of our baseline result, though they may be smaller in magnitude. The downsides to this alternative subsampling is that it looses some power (as could be expected with smaller noisier shocks), yet several SDID coefficients maintain their significance. We also show that the subsampling can be dropped entirely and still yield significant effects when multiplying asset returns by the sign of the shock. The resulting coefficients measure the excess returns caused by the cross-listing in the direction of the shock only, which possesses the right sign at all horizon though they are again lower in magnitude.

6. Stock heterogeneity

The downside to the causal nature of the identification presented in the previous section is that it only captures part of the currency denomination channel. Cross-listing effects are only part of the channel, such that our estimates of its size may only give a lower bound. We thus provide further evidence based on cash flow denomination and stock heterogeneity, which – although not causal – hints at the importance of parity movements.

We use the 212 individual Swiss stocks i, which we aggregate into J groups. We then analyze the sensitivity on impact of each group j to purged exchange rate shocks by interacting the exchange rate shocks with group dummies:

$$\Delta p_{i,t} = \alpha + \sum_{j=1}^{J} \beta_j \left(x_{i,j,t} \times z_t \right) + \sum_{j=1}^{J-1} \alpha_j x_{i,j,t} + \epsilon_{i,t} \,, \tag{6}$$

where $x_{i,j,t}$ is a binary variable that equals one if stock i belongs to group j so that α_j captures group fixed effects. The response of group j to the exchange rate shock is thus given by β_j. We explore four possible ways of grouping firms: by sector, size, share of foreign sales, and cross-listed presence in the US. The groups constructed from continuous variables are created such that the number of firms in each group is approximately equal.

The share of foreign sales aim to proxy the share of foreign cash flows, which we cannot observe directly since it is not part of mandatory reporting requirements. Because sales are one of the largest sources of cash flows for firms, is it immediate that they should proxy the

total share of foreign cash flows. It is also likely that a firm that sells a large part of its production abroad is also likely to relocate most of its production and other cash flow abroad, which decreases several sources of expenses including transportation, labour, and exchange rate conversion costs.

Our analysis indicates that the response of stock prices to exchange rate shocks are partially driven by the currency denomination of the underlying cash flows. Because the exact decomposition of cash flow currencies or country of production is not part of any of the mandatory filling requirements for Swiss firms, neither in their financial nor cash flow statements, we use several proxies for the share of foreign cash flows.[40] Mainly, we use the ratio of foreign sales over total sales, which should accurately approximate the share of foreign cash flows for most firms, and supplement it with the firms' market capitalisation, industry, product exchange rate pass-through, and cross-listing. The response is increasing with the proportion of cash flows denominated in foreign currencies. We show that the stock prices of international foreign-oriented firms are close to five times more sensitive to the shocks than those of domestically oriented firms. In line with this, firms whose products have a higher pass-through to consumer prices, that are cross-listed in the US, that are in more international sectors (such as healthcare, tourism, retail, industrial, and technology) and that are larger are more sensitive to exchange rate shocks. All of these characteristics are directly linked to the proportion of foreign cash flows of firms and to how foreign-oriented they are, though we cannot formally test the accuracy of the proxy. Accordingly, our results contradict the hypothesis that asset prices fall after a currency appreciation because of worsened domestic economic conditions. If that were true, domestically oriented firms should be more impacted by the shocks than firms that have close to no domestic business and for which the domestic currency does not matter for the production or sale of their products.

These results should be interpreted as suggestive given the methodology and data limitations. First, because they rely on a cross-sectional analysis rather than exogenous variations, unlike the previous sections. Second, because we use noisy proxies of the currency denomination of cash flows. Lastly, because these characteristics are fixed in time at the end of our sample,

[40] We additionally do not find any evidence of the voluntary disclosure of this information for any major Swiss firm, nor is it part of the mandatory filling of firms cross-listed on the US market via ADRs.

with no time-varying firm characteristic being available in our dataset for a large-enough portion of Swiss stocks.[41] There is thus some degree of measurement error in those estimates which we cannot account for.

To what extent currency denomination drives the price responses is first seen via differences in the currency denomination of the stocks' cash flows. A second set of supporting evidence is given by the stocks' degree of international substitutability, for which the cross-listing of stocks permits us to provide further evidence. We discuss these two heterogeneity dimensions in turn.

6.1. Currency denomination of cash flows

The role played by cash flow denomination is well illustrated by examples of the three firm categories discussed in Section 2. Over the two days following the large and exogenous Swiss franc appreciation shock in January 2015, the stock price of Swiss Prime Site, a *domestically oriented* firm, fell by 3%, Nestlé, an *international* firm, by 13% and Swatch, an *exporting* firm, by 22% (Figure 9).

Swiss Prime Site only operates in the Swiss real estate market, and its cash flows are entirely denominated in Swiss francs. Its stock price barely reacts to the exchange rate shocks.

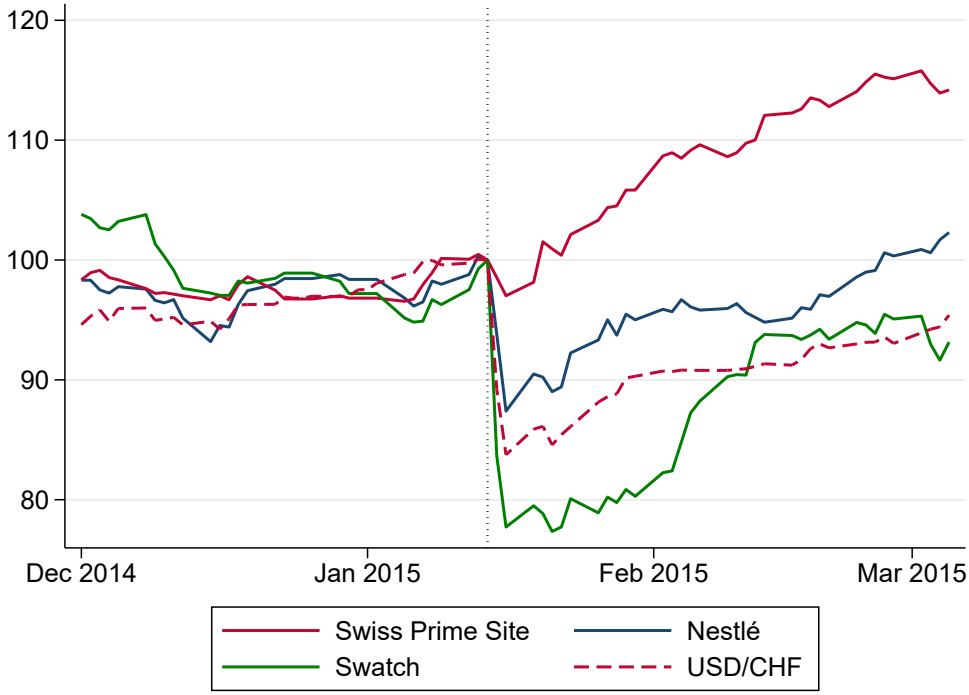
Nestlé produces and sells food and beverage products throughout the world. The Swiss market represented only 1.2% of Nestlé's total sales in 2022. Its cash flows are thus largely denominated in foreign currency, mostly in US dollars. While exchange rate movements do not necessarily affect profits expressed in foreign currencies, they do affect profits expressed in Swiss francs.

Swatch produces watches in Switzerland but sells almost all of them abroad.[42] Exchange rate movements thus affect the firm's revenues but not its costs, in turn affecting its profitability in foreign currencies. Moreover, exchange rate movements also affect the conversion of profits into Swiss francs. The appreciation shock therefore decreased Swatch's profitability by relatively

[41] One indirect test to ensure some degree of time-consistency is to check whether the ranking of firms in their estimated sensitivity to exchange rate shocks is somewhat stable over time. We measure sensitivity as the on-impact reaction of asset prices to the purged shock, then rank firms based on that beta. Regressing firms rank in 2000-2012 against their rank in 2013-2023 with a constant yields a confidence interval of 0.27-0.55, and the Spearman correlation is 0.41 with p-value below 0.00001. They are thus rather stable, though there is some jumping that may be due either to estimation error (since both ranks are estimated in separate noisy regressions) and partially to unaccounted time-shifts.

[42] 92.3% of Swatch's total sales were made abroad in 2022.

Figure 9: Three Swiss stock prices around the January 2015 Swiss franc appreciation



Notes: Series in Swiss franc and indexed to 100 on the day before the January 15, 2015, announcement (vertical line), when the SNB discontinued the EUR/CHF minimum exchange rate. Source: Refinitiv Datastream.

more than that of Nestlé.[43]

It is worth noting that the difference in the observed responses between Nestlé and Swiss Prime Site cannot be easily explained by a change in domestic macroeconomic conditions. The widely discussed mechanism through which the exchange rate impacts asset prices via altered domestic fundamentals (see, e.g., Engel and West, 2005) does not dominate in Figure 9. For this to be the case, Swiss Prime Site should have been more affected than Nestlé, because it relies entirely on Swiss domestic demand whereas Nestlé operates almost exclusively abroad. Changes to the economic conditions that firms operate in—as in explanations based on the current account (e.g., Dornbusch and Fischer, 1980) or on aggregate domestic demand (e.g., Gavin, 1989)—thus cannot explain the observed stock price responses.

We show that variations in stock price responses can instead be explained to a large extent

[43]Stock prices are linked to their expected discounted cash flows, be it at the firm's cash flow (Ma and Kao, 1990) or dividend (Black and Scholes, 1974) levels. The observed price declines of exporters such as Swatch can also reflect an increased currency risk (Karolyi and Stulz, 2003).

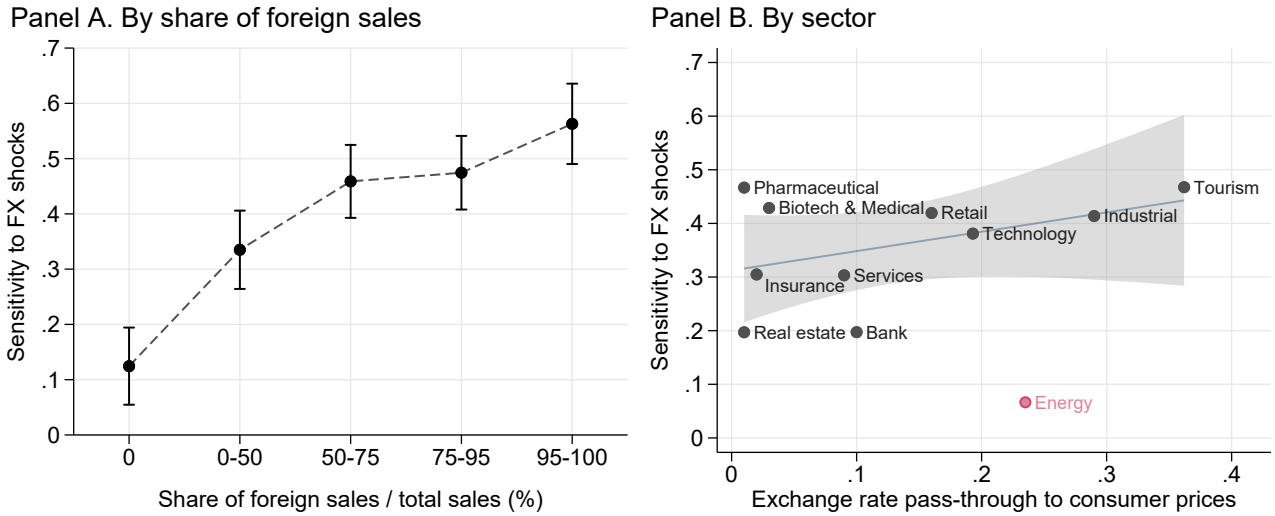
by the currency denomination of the firms' cash flows. This is seen in Figure 10, which plots the price responses of the firm groups that are obtained from specification 6. In Panel A, firms are grouped by the proportion of their sales that are in foreign currencies.[44] This simple ratio can explain wide variations in stock price responses. With a price response of just 0.12, purely *domestically oriented* firms (such as Swiss Prime Site) are far less sensitive to the exchange rate shock than firms with foreign sales. In line with the *currency denomination* hypothesis, the price response is increasing in the foreign sales ratio. The response is as high as 0.55 for *international* firms (such as Nestlé), which have a foreign sales ratio of at least 95%.

The role played by cash flow denomination is further corroborated when instead considering the transmission of the exchange rate to the prices of goods and services. One way to measure how exposed the income of firms is to the exchange rate (such as via currency denomination) is the exchange rate pass-through to consumer prices. We find that the economic sectors[45] with higher pass-through estimates also display higher stock price responses to the exchange rate shocks. To see this, Panel B of Figure 10 plots the *sectoral* responses of stock prices to the exchange rate against the corresponding sectoral exchange rate pass-through to consumer prices (computed for Switzerland by Oktay, 2022). Sectors with more sensitive consumer prices, such as tourism and industrial, display a sharper stock price response to exchange rate shocks. In contrast, sectors with a lower pass-through (such as real estate or banking) are associated with weaker responses. One outlier is the energy sector, which is omitted in the regression line of Panel B. Although energy prices are found to be highly sensitive to exchange rates (see Oktay, 2022), energy stock prices do not respond substantially to our exchange rate shocks because energy prices are typically administratively set in Switzerland. In other words, changes in energy costs are passed on to consumers. This implies little variation in the net cash flows generated by energy stocks, which leaves their valuations relatively unaffected. The sectoral exchange rate pass-through is linked to the average sectoral share of foreign sales with a correlation coefficient of 0.43, showing that the products that are most affected by exchange rate shocks are also those that are the most exported.

[44] There is approximatively the same number of firms in each of the 5 obtained groups.

[45] We group the 212 Swiss stocks into 11 economic sectors. This grouping fits the Swiss stock market, which contains several financial and health firms, and permits us to highlight the specific cases of tourism-related and energy firms.

Figure 10: Stock price responses and heterogeneity in cash flow denomination



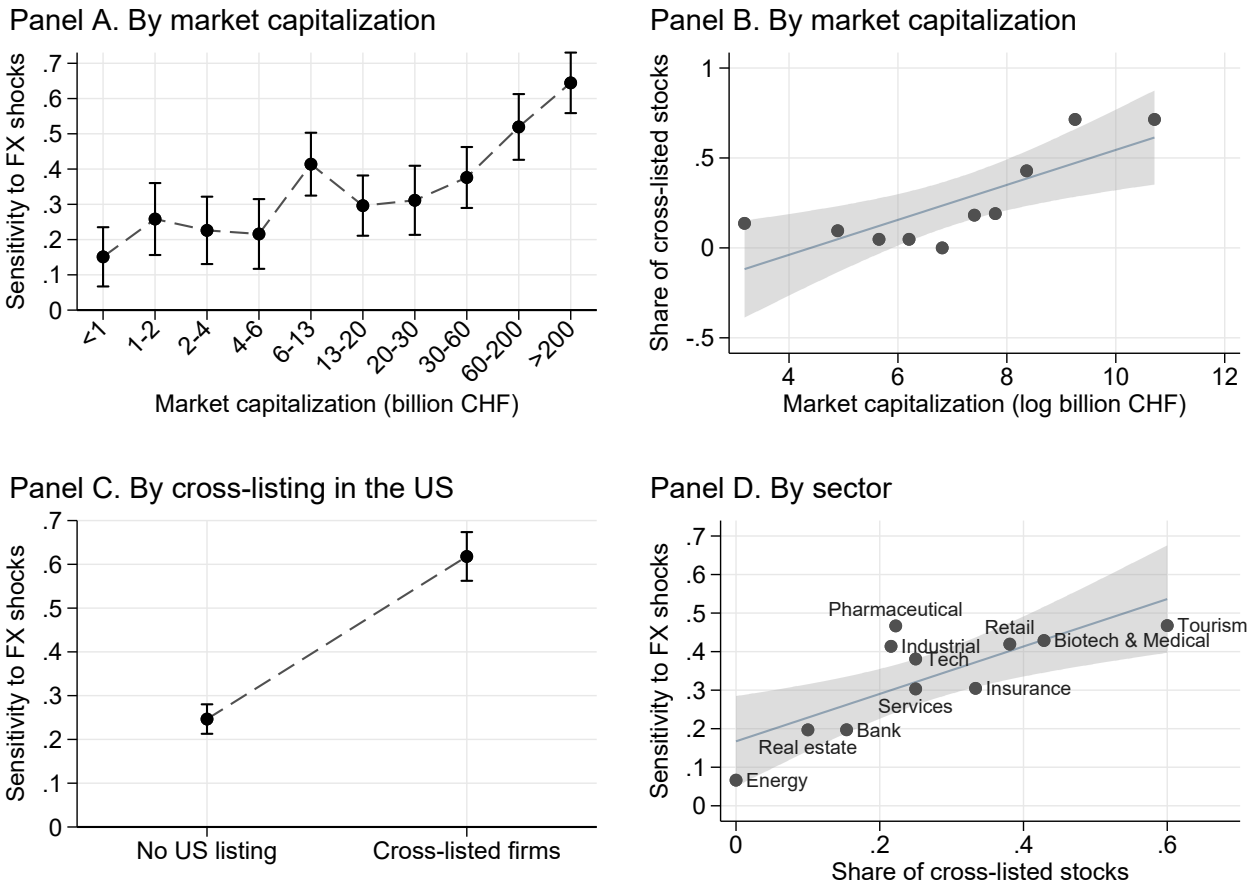
Notes: Using specification 6, 95% confidence are intervals given by whiskers (Panel A) and the grey area (Panel B). Sensitivity to FX shocks is an elasticity (hence a hundred times smaller than that reported in Figure 3). Foreign sale ratios are as of December 2022. Exchange rate pass-through estimates for Switzerland are from Oktay (2022). As discussed in the text, the regression line in Panel B omits the energy sector. The coefficient of the slope in Panel B is 0.361 (p-value 0.206).

6.2. Degree of international substitution

Another way to illustrate how currency denomination drives the stock price responses to the exchange rate is via their degree of international substitutability. The sensitivity of stock prices is partly driven by the degree of substitution of stocks across markets. For instance, Griffin and Stulz (2001) show that the returns of industries that produce traded goods are more sensitive to the exchange rate. In our case, a currency appreciation makes domestic stocks relatively more expensive for international investors since they have to convert the stock price into their reference currency. When the Swiss franc appreciates, foreign-based investors have an incentive to sell some of their now-higher Swiss shares (say, Nestlé) to buy foreign shares that are to some degree substitutable (say, PepsiCo or Unilever). The incentive for this portfolio substitution prevails until the corresponding stock prices adjust to respect currency-adjusted price parity.

Our results show that stocks with a higher degree of international substitution display sharper price reactions to the exchange rate. Naturally, larger firms tend to sell their products abroad and are thus more directly comparable with foreign competitors. In line with this, our estimated price responses are increasing in the stock's market capitalization (see Panel A in Figure 11). It is worth noting that our results should not be weakened by currency hedging.

Figure 11: Heterogeneity of international substitution



Notes: Using specification 6, 95% confidence intervals are given by whiskers (Panels A and C) and the grey area (Panels B and D). Sensitivity to FX shocks is an elasticity (hence a hundred times smaller than that reported in Figure 3). Market capitalizations and cross-listing shares as of December 2022. The coefficient of the slope is 0.097 for Panel B (p value 0.007) and 0.615 for Panel D (p value 0.005). The regression results of are displayed in the Online Appendix Table A6.

Firms cannot hedge indefinitely; cash flows are eventually affected by currency movements. In addition, because hedging is expensive, we would expect the larger firms to resort relatively more to it. Despite this, Figure 11 shows that larger firms display sharper stock price responses to our exchange rate shocks. These findings add to the existing result of Hau et al. (2010), who showed that countries with a higher degree of international stock substitutability have sharper exchange rate responses to an exogenous change in equity index representation. Our results obtained from our identification of exchange rate shocks permits us to instead show a corollary result. Namely, higher substitutability also enhances the stock price response to an exogenous change in the exchange rate.

Another way to measure the degree of international substitutability across stocks is via

cross-listing. In line with the law of one price, the price response of cross-listed firms to the exchange rate is substantially more marked. As described in Section 4.1, 54 of the 212 Swiss stocks are also listed in the US via an ADR. Unsurprisingly, larger firms are more likely to be cross-listed (see Panel B in Figure 11). The Swiss firms that are cross-listed in the US are of particular interest because they offer a perfect substitute to foreign investors. Panel C in Figure 11 shows that cross-listed firms have an initial price response of 0.60, which is both significantly and sizably different from the response of firms only listed in Switzerland (with a response of just 0.25). The presence of cross-listing appears to be important quantitatively, as it explains a considerable portion of the price response variations observed across sectors. This is shown in Panel D, which plots the proportion of cross-listed stocks against our estimated price responses at the sectoral level. The least impacted sectors are energy, real estate and banks. These sectors are also those that have the smallest proportion of cross-listed firms. Similarly, tourism-related firms and biotech stocks are among the most impacted and have a large share of their firms cross-listed in the US. Accordingly, cross-listed firms appear to react more sharply to exchange rate shocks than single-listed firms. The sectoral responses partly account for the cash flow denomination effect that was documented in the previous section (and illustrated in Panel B of Figure 10). In Section 5, we will present more causal evidence of cross-listing via the staggered introduction of ADR.

6.3. Evidence from ADR excess returns

How is an exchange rate shock expected to affect the relative performance of US-based ADR prices of Swiss stocks compared to their US peers?

If the exchange rate mostly impacted stock prices via altered *economic conditions*, an appreciation of the Swiss franc would lead ADR prices to perform relatively worse than their US peers. By weakening economic conditions in Switzerland, an appreciation would lead Swiss companies to perform less well than US companies. The return of ADR prices in excess to that of their US peers would thus be positively correlated with our exchange rate shocks. However, if the exchange rate mostly impacted stock prices via the *currency denomination* mechanism, an appreciation of the Swiss franc would lead ADR prices to perform relatively better than their US peers. The return of ADR prices in excess to that of their US peers would thus be negatively correlated with our exchange rate shocks.

We test whether the Swiss stocks listed in the US exhibit excess returns with respect to comparable US firms after exchange rate shocks. To do so, we compare the individual ADR returns $\Delta p_{i,t}^{US}$ to the return of their respective sectoral index $\Delta p_{s,t}^{US}$, measuring the 11 sectors described previously by the corresponding S&P500 indices.[46] For each sector s, the individual excess returns are regressed against the exchange rate shocks:

$$\left(\Delta p_{i,t}^{US} - \Delta p_{s,t}^{US}\right) = \alpha_s + \beta_s z_t + \epsilon_{i,t}\,, \tag{7}$$

where systematic differences in risk between the US-listed Swiss firms and the corresponding US indices are captured via the intercepts α_s. If the mechanism of altered economic conditions dominates, $\beta_s > 0$, whereas $\beta_s < 0$ instead indicates that currency denomination drives the ADR price responses.

The response of the US-based excess returns clearly supports the currency denomination hypothesis. Figure 12 shows a significantly negative relationship between excess returns and the exchange rate shocks, consistent with the large role played by currency denomination. The negative response of the excess returns holds across all sectors (though not significantly for one) and appears homogeneous in terms of statistical significance.

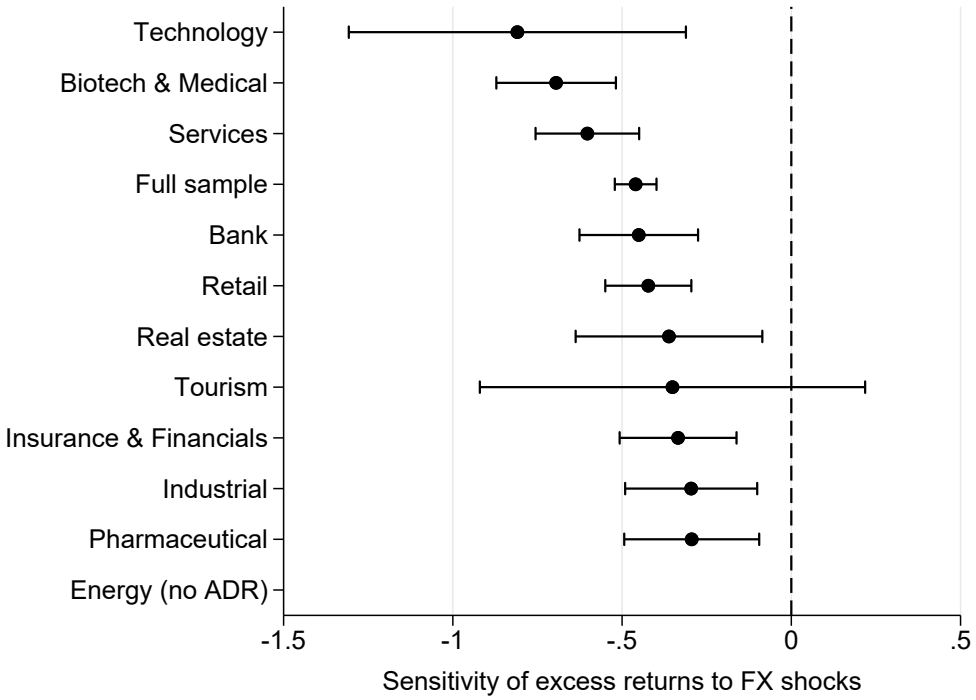
7. Conclusion

We have shown that the reaction of Swiss stock prices to exchange rate shocks reflects a currency denomination effect. Our analysis reveals that stocks with foreign-denominated cash flows are more sensitive to the exchange rate, which is only amplified by the introduction of cross-listings via the law of one price.

In light of the meaningful role played by cross-listing, stock market movements on monetary policy announcement days should be interpreted with caution. The response of stock prices to monetary policy announcements are often mentioned in the press as changes in market expectations about future economic conditions. Similarly, they are used in the literature to identify the nature of central bank announcements in large economies (see, for instance, Jarociński and

[46]The indices used are the S&P500 Banks, S&P500 ES Health Care, S&P500 ES Energy, S&P500 EW Industrial, S&P500 Insurance Brokers, S&P500 Chemicals, S&P500 ES Real Estate, S&P500 ES Consumer Staples, S&P500 Telecom & IT, S&P500 Tech and Datastream US Travel and Tourism index since S&P does not provide a sectoral index for tourism.

Figure 12: Response of ADR excess returns to a (Swiss franc) exchange rate shock



Notes: Sensitivity to FX (USD/CHF) shocks is an elasticity (hence a hundred times smaller than that reported in figure 3). Using specification 7. Whiskers give 95% confidence intervals. Corresponding regression results are displayed in Online Appendix Table A8.

Karadi, 2020 for the US and the euro area). Our results reveal instead that stock price responses are largely driven by the currency denomination hypothesis and that the response is further amplified by the cross-listing of stocks. The price reactions thus do not necessarily reflect the beliefs of market participants about future domestic economic conditions.

In terms of external validity, our findings can be extrapolated to other economies. Since currency denomination drives the stock price responses, economies with domestically denominated assets that are substitutable with foreign assets should be affected similarly to what we documented. Accordingly, the currency denomination effect should be more marked in small-open economies. Moreover, the increasingly large prevalence of cross-listed firms around the world[47] further enhances the role played by the currency denomination channel that we have uncovered.

[47]See Gagnon and Karolyi (2013) for a survey of cross listings as of 2008. The number of cross-listed firms is likely to have increased since then, as shown in Figure 5 for Switzerland.

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