The Speed of Exchange Rate Pass-Through*

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Abstract

This paper analyzes the speed of exchange rate pass-through into importer and exporter unit values for a large, unanticipated, and unusually 'clean' exchange rate shock. Our shock originates from the Swiss National Bank's decision to lift the minimum exchange rate policy of one euro against 1.2 Swiss francs on January 15, 2015. This policy action resulted in a permanent appreciation of the Swiss franc by more than 11% against the euro. We analyze the response of unit values to this exchange rate shock at the daily frequency for different invoicing currencies using the universe of Switzerland's transactions-level trade data. The main finding is that the speed of exchange rate pass-through is fast: it starts on the second working day after the exchange rate shock and reaches the medium-run pass-through after eight working days on average. Moreover, we decompose the pass-through by invoicing currencies and find strong evidence that underlying price adjustments occurred within a similar time frame. Our observations suggest that nominal rigidities play only a minor role in the face of large exchange rate shocks.

Keywords: daily exchange rate pass-through, speed, large exchange rate shock
JEL Classification: F14, F31, F41

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1 Introduction

A central topic of international economics is how exchange rate changes pass through into prices of tradables. The exchange rate pass-through is not only informative about market structures, the pricing and markups of exporting firms, it also determines the cross-border transmission of nominal shocks induced, e.g., by monetary policy. For some time, measuring and explaining the degree of the exchange rate pass-through has been the central challenge of the literature.[1] Recent work, however, has turned attention to the speed at which prices react to exchange rate shocks. Typical estimates for the adjustment period range from 4 to 18 months.[2]

This paper analyzes the speed of the pass-through for a large, unanticipated and unusually 'clean' exchange rate shock. Our shock originates from the Swiss National Bank's (SNB) decision to lift the minimum exchange rate policy of one euro against 1.2 Swiss francs on January 15, 2015. This policy action resulted in an appreciation of the Swiss franc against all major currencies and to a permanent appreciation by about 11% against the euro. We analyze the response of unit values to this exchange rate shock at the daily frequency for different invoicing currencies, using the universe of Switzerland's transactions-level trade data.

The central result of our analysis is that the pass-through of the exchange rate shock into unit values materialized extremely fast: for imports it started on the second working day after the shock and the medium-term pass-through was reached after six further working days. Similarly for exports, the exchange rate pass-through responds almost immediately to the Swiss franc shock. Although the estimated rate of pass-through is slightly lower for exports than for imports, the speed of exchange rate pass-through is similarly fast.

We present estimates of the degree and the speed of the pass-through separately by invoicing currency. This separation is key to infer the degree of nominal rigidities. For example, under strong nominal price rigidities, when underlying transactions are invoiced in euro, the Swiss franc-denominated unit values react 'mechanically' and instantaneously to exchange rate changes. Conversely, Swiss franc-denominated unit values of Swiss franc-invoiced transactions do not react under the same strong nominal rigidities. Estimating the exchange rate pass-through into unit values

[1] See Dixit (1989) and Feenstra (1989) for early theoretical and empirical contributions, Menon (1995) for a survey of the earlier literature.

[2] Campa and Goldberg (2005) find that most of the pass-through materializes after two quarters, in Gopinath et al. (2010) it requires about 18 months to be completed.

by pooling transactions of all invoicing currencies thus yields results of limited information content. In this paper, we document a fast exchange rate pass-though into Swiss franc-denoted unit values for transactions that were originally invoiced in Swiss francs. This finding implies that underlying price adjustments materialized promptly. Finally, a precious feature of our data is that trade transactions are recorded at the daily frequency. This information puts us in the comfortable position to estimate the pass-though on an unmatched time grid.

The main message of our remarkably fast pass-through finding is that the suddenness and size of an economic shock can quickly undo frictions defined by staggered contracts or lengthy deliveries. Our findings suggest that nominal rigidities did unravel in a matter of days after the January 15, 2015 exchange rate shock. Of course, this does not imply that nominal frictions are nonexistent. Instead, our findings indicate that firms are able to adjust prices rapidly if confronted with large and sudden changes to their operating environment. This observation is especially striking in the context of cross-border trade, where transport is time-intensive and contracts could be expected to be written with a horizon of quarters, introducing the corresponding nominal frictions.[3]

In view of the fact that price adjustments are rather infrequent in normal times, we read our findings as strong support for state-dependent pricing frameworks à la Dotsey et al. (1999) and Golosov and Lucas (2007). By documenting that a 11% exchange rate shock induces responses very similar to those of full price flexibility, our study may in that respect add valuable information for refined calibrations of state-dependent pricing models. We thus add to an important event study to the recent work by Alvarez et al. (2016), who argue that state and time dependent models differ only when it comes to the response to large shocks. Specifically, although the frequency of adjustment in tranquil times is well documented and the according parameters are readily calibrated, we provide rare evidence on the reaction of unit values in response to large, permanent, and unanticipated shocks.[4]

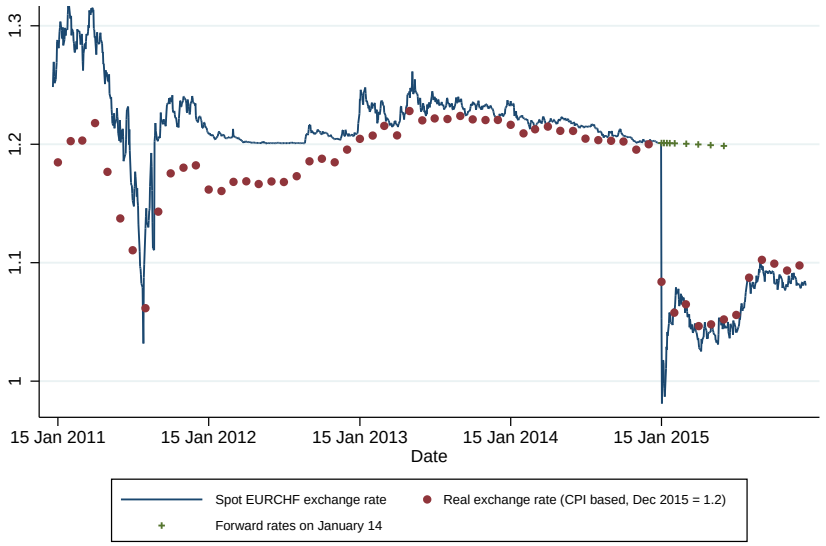
In the more technical dimension, our contribution is to estimate the pass-through of a sudden, unanticipated and, as we argue, exogenous ex-

[3]Foreign goods shipped to the United States spend about two months in transit, see Amiti and Weinstein (2011). Letters of credit, the most common means of trade finance, cover a typical span of 90 days, see BIS (2014).

[4]Our findings are thus in line with Vavra (2013) who shows that "greater volatility leads to an increase in aggregate price flexibility." Relatedly, large shocks are thus likely to impact inflation persistence and the determinants of Phillips Curves, as analyzed in Bakhshi et al. (2007).

change rate shock at daily frequency. The analysis at the daily frequency does only make sense when the underlying shock is sharp and can be unambiguously identified. The large exchange rate shock that originated from the SNB's policy decision is perfectly suitable in that regard. Figure 1 illustrates the dynamics of the nominal bilateral exchange rate (solid line) and the monthly real exchange rate (dots) starting January 1, 2011 through December 31, 2015. On January 15, 2015, the series shows a persistent appreciation of about 11% until beginning of July 2015, at which point the Swiss franc depreciates significantly. Apart from a temporary overshooting, the fluctuations before and after this shock (until July 2015) are mild relative to the drop itself. Further, the forward rates (plus signs) from January 14, 2015, which are around the 1.2 threshold, indicate that the January 15, 2015 decision was not anticipated by financial markets.

Figure 1: EURCHF exchange rate from January 2011 to December 2015



Sources: SNB, Datastream

Gauging the flexibility of international prices in response to a large shock at the daily frequency is a novelty. The gains from working with an unusually detailed dataset containing the day and invoicing currency of transactions require us to compromise in other dimensions. The dataset do not allow us to identify exact products as Gopinath et al. (2010) and thus cannot report

the frequency of price changes or pass-through rates conditional on price changes. We rely instead on 8-digit HS product classes similar to Berman et al. (2012). Although this latter study uses firm level data, we are only able to proxy those with a postal code-product combination.

Our findings contribute to several strands of the pass-through literature. Closest to our study is Burstein et al. (2005), who document that import and export prices of tradable goods respond rapidly to large exchange rate shocks, although retail prices of tradable goods are much slower to adapt due to retail costs and general local components. Our study focuses on unit values at the border, confirming that these unit values react promptly to a large exchange rate shock. In addition, we make two important advancements. First, we refine the time-grid of the analysis, showing that the unit values appear to react very quickly even at the daily scale. Second, we disentangle price adjustments by groups of invoicing currencies. This latter contribution is important, because adjustments of export and import prices in Burstein et al. (2005) may mechanically occur if a large share of traded goods is invoiced in foreign currencies (a presumption that is likely in the sample of developing and emerging countries considered, see Kenen (2011)). Our analysis, instead, shows that Swiss export and import unit values measured in Swiss francs when originally invoiced in Swiss francs. This observation complements Burstein et al. (2005) in that it allows us to draw conclusions about nominal rigidities.

Our findings connect more broadly to the literature that addresses the degree, determinants, and characteristics of the (medium-run) exchange rate pass-through. The average degree of an economy's exchange rate pass-through into import prices is typically found to vary between 0.4 (a 10% appreciation in the exporter's exchange rate is associated with a 4% rise in import prices) and 1 for most countries (see Campa and Goldberg (2005), whose estimate for Switzerland is 0.9) and varies across sectors (e.g., Feenstra (1989)).[5] Our estimates of 0.9 exchange rate pass-through for imports (0.7 for imports invoiced in Swiss francs) is in line with these previous estimations.[6]

[5] A fast growing literature has identified number of firm- and product-specific determinants of the exchange rate pass-through. Recent empirical contributions highlight the role of firm size, e.g., Berman et al. (2012), the share of imported inputs, e.g., Amiti et al. (2014), or the role of product quality, e.g., Chen and Juvenal (2013) and Auer et al. (2014).

[6] There is a large literature on optimal invoicing currency, for example, Bacchetta and Van Wincoop (2005), Engel (2006), and Goldberg and Tille (2008). Our study is silent on this issue, but similar to Gopinath et al. (2010) and Devereux et al. (2015) take instead

Regarding our more specific question of the speed of price adjustment, the existing empirical evidence suggests that in normal times this speed is rather limited. Campa and Goldberg (2005) observe that "[m]ost of the pass-through response occurs over the first and second [quarter] after an exchange rate change" although Gopinath et al. (2010) analyzing more detailed transactions-level import prices find that the pass-through requires about 18 months to be completed. Burstein and Jaimovich (2012), in turn, find quicker adjustments using Canadian and U.S. scanner data. They show that retail prices adjust to exchange rate shocks within about four months. Gorodnichenko and Talavera (2014) show that price adjustment is even faster in the particular case of online markets. We complement this rich set of findings by analyzing the speed of exchange rate pass-though into unit values of the universe of traded products at the daily frequency. We attribute the exceptionally fast pass-through to the fact that we analyze a particularly large exchange rate shock. Although firms may optimally delay price adjustment to small shocks (see, e.g., Corsetti et al. (2008) and Alvarez et al. (2016)), the need to adjust prices can be quite different in the face of large shocks.

Our work also connects to the strand of empirical research on episodes of large exchange rate changes. Previous studies have examined large exchange rate devaluations mainly for developing countries. Verhoogen (2008) considers the large Mexican devaluation in 1994 as the exchange rate shock. Flach (2014), for example, uses the depreciation of the Brazilian real to identify its causal effects on export prices. Further, Cravino and Levchenko (2015) use the devaluation of the peso during Mexico's "Tequila Crisis" and show its substantial distributional impact. Alessandria et al. (2015) consider export expansion in emerging markets after a large devaluation. Close to our paper, Efing et al. (2015) use the Swiss franc exchange rate shock to examine the impact on investor behavior and the real economy. We contribute to this literature on large exchange rate shocks in that we analyze the pass-through of a single-day, large, and unanticipated exchange rate appreciation. Our large exchange rate shock, moreover, is novel to the literature in that it concerns an industrialized country and a major currency.

By suggesting fast and immediate price adjustments after a large exchange rate shock, we connect to the empirical literature on state-dependent pricing. Using Mexican consumer price data, Gagnon (2009) shows that the frequency of price adjustments comoves with inflation and concludes that "pricing models should endogenize the timing of price changes if they wish

this choice as given.

to make realistic predictions at both low and high inflation levels." Our findings support this general message.[7] Related empirical work addresses international price settings using large micro-datasets at ever higher frequencies. Auer and Schoenle (2016) and Gopinath et al. (2010) work with similar datasets at the monthly frequency, although Burstein et al. (2005) and Gorodnichenko and Talavera (2014) that use 'scanner' (barcode) data and web-based retailers at the weekly frequency.

Finally, we claim that our work makes advances by addressing the endogenous nature of exchange rates. It is well known that traditional pass-through estimations suffer identification problems because of the endogeneity of the exchange rate.[8] Our shock, instead, was unanticipated and 'purely nominal'. In other words, the shock does not result from fundamentals so that our estimated price adjustments are not mixing reactions to the nominal exchange rate and, simultaneously, to shocks to fundamentals.[9]

The remainder of the paper is organized as follows. Section 2 describes the nature of the exchange rate shock and the transactions-level trade data. Section 3 first presents the empirical results at the monthly frequency. This is done to facilitate comparison with the previous literature, which primarily provides estimates at the monthly frequency. The main results at the daily frequency are then exposed. Section 4 presents further robustness checks on the speed of price adjustment. Section 5 concludes.

[7] Feltrin and Guimaraes (2015), for example, use prices of Brazilian CPI behavior in Brazil following the large devaluation of the Brazilian real in 1999 and show that the frequency of adjustment is higher right after the depreciation. Grinberg (2015) uses micro data from Mexican CPI and shows that "the effects of nominal rigidities in retail prices are quantitatively small and short-lived", concluding that models with "time-dependent nominal frictions in prices (e.g. Calvo prices) can substantially underestimate the response of prices to a large depreciation, implying large real effects of the nominal shock".

[8] Corsetti et al. (2008) observe that "the estimation bias in pass-through regressions is a function of the volatility of the nominal exchange rate and the covariance between the exchange rate and the determinants of import prices." The authors present a model of variable firm markups and sticky prices where exchange rates and nominal prices are driven by productivity shocks. With concrete reference to a specific good, Gopinath et al. (2010) write that "the Canadian exchange rate is more likely to be driven by the price of its main export commodities than the other way round." Although this criticism is especially prevalent for 'commodity currencies' (see Chen and Rogoff (2003)), reverse causality will always affect traditional estimation to some degree.

[9] In the appendix, we also discuss the possibility that lagged exchange rates bias pass-through estimates.

2 Data description

The identification strategy to estimate the speed of exchange rate pass-through relies, first, on a large and exogenous exchange rate shock and, second, on detailed transactions-level trade data at the daily frequency. The discussion is divided into two subsections. The next subsection discusses the SNB's exchange rate floor and why its lifting has generated an exogenous shock. Thereafter, we discuss the main features of the Swiss customs data.

2.1 The exchange rate shock

This subsection argues that the appreciation was exogenous to import and export pricing. Moreover, it documents that the exchange rate shock was preceded by an extended period of exceptional exchange rate stability.

The SNB pursued a policy of a minimum exchange rate of 1.2 Swiss francs against the euro from September 6, 2011 to January 15, 2015. This unconventional policy was introduced in response to the appreciation pressures on the Swiss franc during the summer months in 2011. In particular, the Swiss franc had appreciated against the euro by more than 20% in June and July 2011. At the time, the SNB argued that the rapid appreciation of the Swiss franc would harm the Swiss economy through imported deflation.[10] Throughout the period of the minimum exchange rate policy, it was repeatedly mentioned that the Swiss franc was overvalued and that the SNB was fully committed to the policy.

Figure 1 in the introduction plots the nominal EURCHF exchange rate (daily data), the real EURCHF exchange rate (monthly data) and the EURCHF forward rates on January 14, 2015.[11] During the period of the minimum exchange rate (September 6, 2011 to January 15, 2015), the Swiss franc fluctuated between 1.2 and 1.25. Yet for most of the floor's period, the Swiss franc hovered near the minimum rate. The figure also shows that the real EURCHF exchange rate (available at monthly frequency) closely tracks the nominal EURCHF over the entire period from January 2011 to June 2015. The period of exchange rate stability ended abruptly with the lifting of the floor on January 15, 2015. The timing of the SNB's announcement was motivated by the changing global market conditions, in particular,

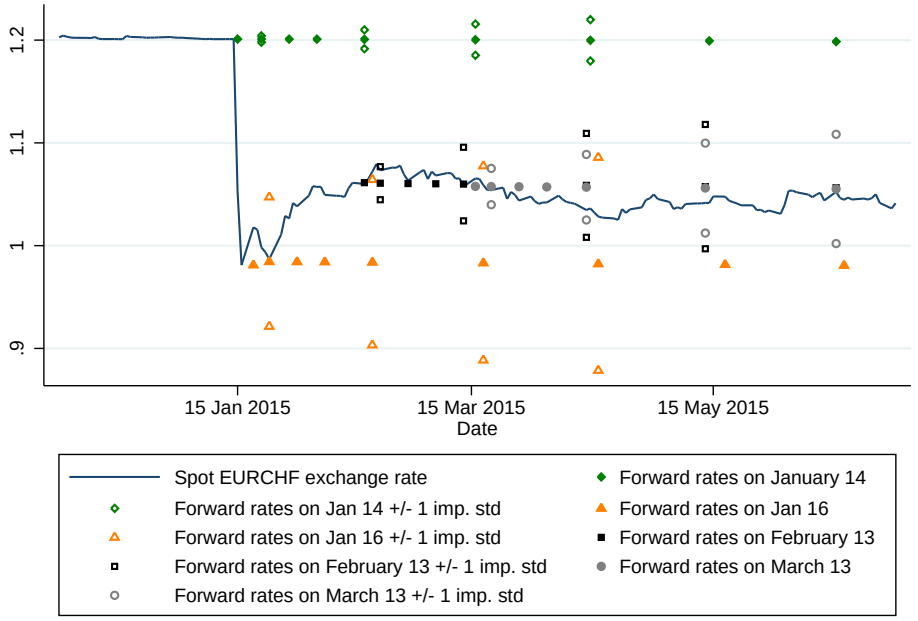
[10] The SNB press release from September 6, 2011 stated "[t]he current massive overvaluation of the Swiss franc poses an acute threat to the Swiss economy and carries the risk of a deflationary development."

[11] The real exchange rate is constructed using the CPI indices from the euro area and Switzerland and is normalized to 1.2 for December 2014.

increasing differentials in monetary policy actions.[12] We therefore take the EURCHF exchange rate shock as exogeneous to the pricing strategies of importing and exporting firms.

The SNB's announcement to terminate its policy of the minimum exchange rate took financial markets by storm.[13] Figure 1 shows that the Swiss franc appreciated by 11% against the euro by the end of January. The daily EURCHF rate averaged 1.057 for the post-minimum exchange rate period until June 30, 2015.

Figure 2: EURCHF spot rates and forward rates with implied standard deviations from January 2015 to June 2015



Sources: SNB, Datastream, own calculations.

[12]The SNB press release from January 15, 2015 stated "[r]ecently, divergences between the monetary policies of the major currency areas have increased significantly a trend that is likely to become even more pronounced. ... In these circumstances, the SNB concluded that enforcing and maintaining the minimum exchange rate for the Swiss franc against the euro is no longer justified."

[13]The list of market commentary regarding the SNB's decision on January 15, 2015 is long. One of many examples is from Reuters, see http://www.reuters.com/article/us-swiss-snb-cap-idUSKBN0KO0XK20150116.

The exchange rate shock was not only large and persistent, but it was also unanticipated. Figure 2 zooms in on January 2015 and contains information on EURCHF forward rates. More specifically, it shows that the forward rates from January 14, 2015, i.e., one day before the SNB's announcement (diamonds), stayed at the minimum rate of 1.2. Note that the +/- implied standard deviations of the forward rates are also included when available. The implied standard deviations of the January 14 forward rates are small, indicating little uncertainty.[14] Forward rates quoted on January 16, 2015 (triangles), February 13, 2015 (squares) and March 13, 2015 (circles) are also shown. These forward rates first dropped to about 0.98 the day right after the announcement before stabilizing at just under 1.06 in February and March. The implied standard deviation on January 16 is substantially higher than before the shock, indicating a higher uncertainty, and lessens substantially in February, which is consistent with the shock having been absorbed by market participants and the new exchange rate equilibria having been reached.

The sum of these observations underpin the view that the exchange rate drop was not only large but also unanticipated and exogenous to firm's pricing decisions.

2.2 Swiss customs data

The source for the trade data is the Swiss Customs Administration or Eidgenössische Zollverwaltung (EZV), which records Swiss customs transactions.[15] The full available sample is from January 1, 2012 to December 31, 2015. The data include information on the value in Swiss francs (f.o.b. for exports and c.i.f. for imports), mass, product, partner country, transaction date, Swiss postal code, invoicing currency, and transportation mode (road, plane, rail, water, pipeline, self-propelled). These data are reported on the transactions level at the daily frequency. The data cover the vast majority of legal customs declarations made to the Swiss Customs Administration. Some transactions with a simplified custom declaration procedure are not

[14] For a study looking at wether the announcement was anticipated or not, see Mirkov et al. (2015) who look at various Swiss francs options quotes in a narrow time frame around the announcement of the removal of the floor and conclude that no abnormal behavior proceeded the removal of the floor.

[15] The geographical coverage is Switzerland, Liechtenstein, and the two enclaves Campione d'Italia and Büsingen.

included in our dataset.[16] The unit of observation is one transaction.[17] We focus on trade with the euro area.

In section 3.1, we provide monthly results based on the full sample, while in section 3.2 we provide results at the daily frequency based on a reduced sample size. Table 1 provides statistics for the transactions data for the sample used in the daily estimation (January 1, 2014 to June 30, 2015), the pre-shock period (January 1, 2014 to January 14, 2015), and the post-shock period (January 15, 2015 to June 30, 2015). The number of transactions for imports is 29.2 million and for exports 16.3 million. Both for imports and exports the share of euro invoicing is around two-thirds. Differences in the share of euro invoicing between the pre- and post-shock period are small.[18]

Each observation contains an 8-digit HS number as well as a 3-digit statistical key specific to the EZV dataset. We refer to the combination of HS number and statistical key as an "augmented 8-digit HS number". Each observation contains the net mass of the shipping expressed in kilo. Roughly one fourth of our observations also contain a "supplementary unit", which can be liters, meters, squared meters, cubic meters, karat, pieces, pairs, or other specific units (e.g., Liter at 15C).[19] We construct unit values by dividing the value of the transaction by the supplementary unit when available and by the mass when not.

Our dataset contains two additional variables, which are key for the empirical exercise.[20] The first key variable is the transaction date. Unlike other trade data, and fortunately for our purpose, the transaction date is not recorded at the monthly but at the daily frequency. More precisely, the transaction date (*Veranlagungsdatum*) reports the day when the customs

[16] Eligible are goods of value of less than CHF 1000.- and weight of less than 1000 kg, non commercial transactions or cultural goods. According to SNB aggregate statistics, these totaled 209 million in exports (or 0.1% of exports covered in our analysis) and 10184 million in imports (or 5.7% of the imports covered in our analysis) for 2014. Note that our dataset does include small transactions that were not declared through a simplified procedure as well.

[17] Thus, we operate with the universe of Swiss trade transactions instead of survey data as in Gopinath and Rigobon (2008) and Gopinath et al. (2010).

[18] Although the difference in the share of invoicing in euro, Swiss francs and other pre and post-shock is statistically significant, the magnitude of the change is small. In the appendix, Figure 8 also informally shows that there is no noticeable systematic switching happening.

[19] For exports, based on the number of transactions, 22.2% have the supplementary unit. Based on value, it is 23.6%. For imports, based on the number of transactions, 24.4% have supplementary units. Based on value, it is 25.7%.

[20] The EZV data have been previously used at the monthly level by Kropf and Sauré (2014) and Egger and Lassmann (2015).

form is filled in and the legal transaction takes place. Given the unique identification of our exchange rate shock – January 15, 2015 – the daily frequency of our data is of great value to identify the dynamics of price reactions, in particular, the speed of exchange rate pass-through.

The second key variable records the currency in which transactions are invoiced. For each custom declaration, we know whether the invoicing currency was either of the following five categories: CHF, EUR, USD, other EU currencies and other currencies. If the transactions are not invoiced in Swiss francs, the value is converted using a specific exchange rate. The exchange rate used for imports is published daily by the EZV. It corresponds to the market exchange rate observed the working day before the declaration is made. For example, if a transaction is declared on a Monday, the Friday exchange rate is used.[21] For exports, the same rule applies in general. However, the monthly average exchange rate or the 'international groups' internal accounting exchange rate can be used if the firm has an according arrangement and is registered with the EZV. The monthly average applicable to a transaction in month, m, is the average of the daily exchange rate observed between the 25th of the month $m-2$ and the 24th of the month $m-1$. The uncertainty as to which exchange rate was used will somewhat complicate the interpretation of our results for the export transactions taking place in January. Unfortunately, since several transactions can be declared under a single custom declaration but the currency of invoicing is reported at the declaration level, it can happen that transactions invoiced in different currencies get classified under a single currency. In these occurrences, the currency covering the most of the declaration's value is entered, and our dataset attributes this currency for all transactions. We remedy this shortcoming by a robustness check restricting the sample to transactions unique to a custom declaration.

The currency information is important not only because the invoicing currency is known to be a crucial determinant of the exchange rate pass-through. More importantly, under sticky prices and by pure mechanics, the exchange rate shock is in the short run (i) fully passed through into import prices in the case when transactions are invoiced in exporter currency and (ii) not passed through at all in the case when transactions are invoiced

[21] The exchange rate is published early in the morning (e.g. 04:30 am for December 14, 2014). Particularly, on January 15, 2015, the exchange rate was published before the SNBs announcement and its value for January 15, 2015 (applicable to the January 16, 2015 transactions) is 1.21303. However, the EZV allowed a non-published exchange rate to be used for transactions registered on January 16 if appropriate justifying documents were produced by importers.

in importer currency. The distinction between CHF, EUR, and all other currencies is therefore crucial to identify the speed of actual pass-through via active price adjustments.

Our analysis focuses on the transactions invoiced in Swiss francs and euros since our exercise concentrates on transactions between Switzerland and the euro area, the vast majority of which is invoiced in either of the two currencies: Figure 3 plots shares of Swiss exports and imports to and from the euro area invoiced in Swiss francs, euros, or other currencies from January 2014 to December 2015 at the monthly frequency. The shares are computed based on the transactions (top panel) and based on the values (bottom panel). The figure conveys two messages. First, almost all trade is invoiced either in Swiss francs or euros. In fact, only 1% of export transactions (and value) was invoiced in other currencies. Second, the respective shares are stable over time and, in particular, do not appear to have shifted the invoicing currency in response to the exchange rate shock in January 2015.

To assess whether firms switch the invoicing currency, Figure 3 also reports the share of transactions (value) that stem from the subset of triplets of HS-product, postal code, and partner country (proxying firms), that have always invoiced in the same currency throughout the 18-month sample. These shares are indicated by the dashed lines, which separate the Swiss franc or euro shares into two areas. The area between the dashed lines consists of transactions from triplets who always invoiced in the respective currency. These are between a quarter to half of the respective shares.[22]

Despite the detailed information on date and invoicing currencies, there are important limitations to the transactions-level data. First, we do not observe prices of unique goods but are limited to the augmented 8-digit categories of the HS classification system, which means that our study relies on unit values instead of prices. The limitation implies, in particular, that we are unable to directly measure price stickiness. Although unit values are generally contaminated by compositional product and quality shifts inside a good category, we argue below that this is unlikely to drive our results.

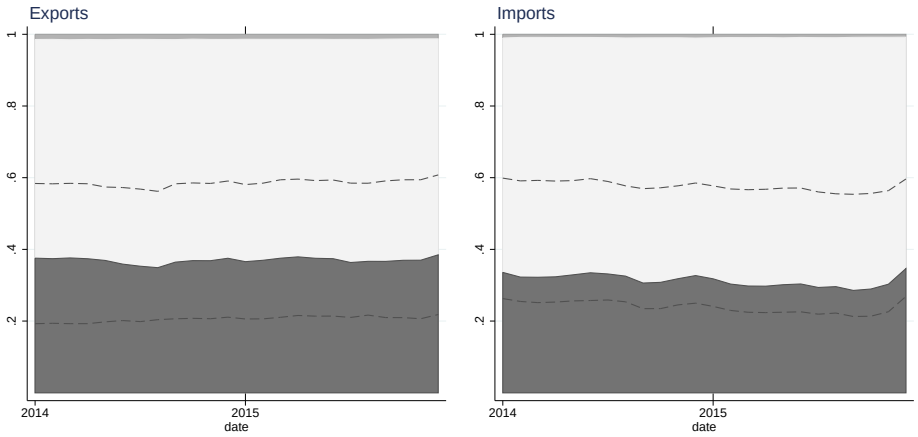
A second limitation of our dataset is that intrafirm transactions are not identified.[23] Thus, we cannot exclude them from the analysis to extract only market price reactions to the exchange rate shock as in Gopinath et al. (2010). We address this shortcoming by analyzing intermediate and invest-

[22] See, Appendix 1 for further information on the extent of switching from one invoicing currency to another in response to the exchange rate shock.

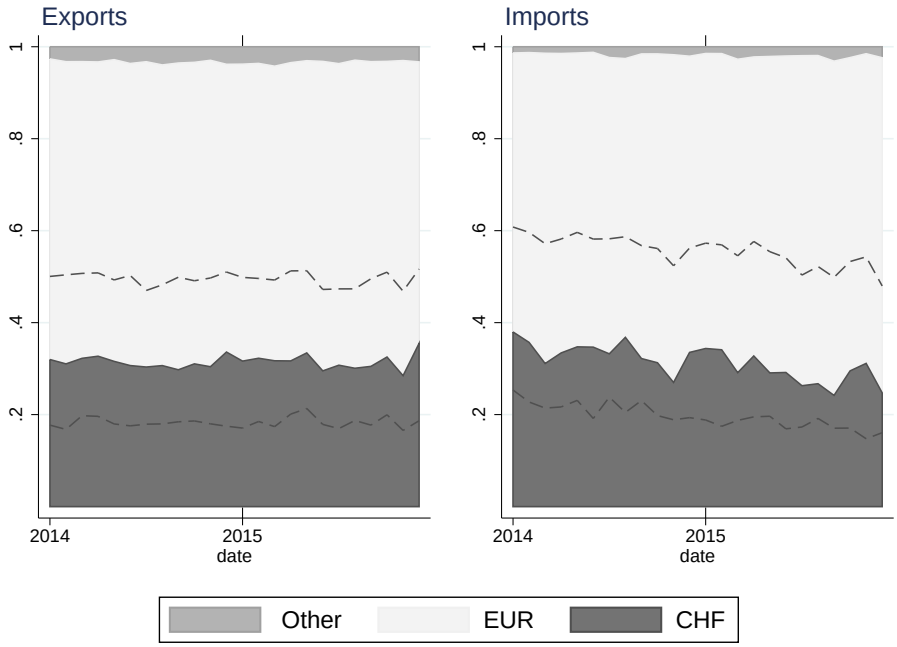
[23] Neiman (2010) shows for U.S. transactions data that prices of intrafirm trade are less sticky, but that the pass-through is still not immediate.

Figure 3: Monthly shares of currency in the Swiss trade with euro area

(a) Based on Transactions



(b) Based on Values



The dark area represents the share of transactions (value) invoiced in Swiss francs, the light area in euros and the gray area in other currencies. The area below the dashed line represents the share of transactions (value) originating from a triplet (postal code - HS - country) that always invoiced in the same currency from January 2014 to December 2015. The area above the dashed line represents the share of transactions (value) originate from a triplet that has invoiced in different currencies.

ment goods separately from final consumption goods in a robustness check and by looking at transactions of small values that are unlikely to be subject to intrafirm trade in robustness checks.

3 Estimation strategy and results

This section presents our main findings. We begin by providing results from a standard pass-through estimation on the full available data, before zooming in on a short window to estimate the daily reaction of unit values to the January 15, 2015 shock.

3.1 Monthly estimations

The total available sample stems from January 2012 to December 2015. Given the high number of transactions this represents, we are unable to run a transactions-level regression on the full time window. To gauge the behavior of the pass-through over the full sample, we start by estimating a standard pass-through regression model similar to Gopinath et al. (2010) at the monthly frequency, on a panel of postal code - augmented HS-classification - partner country triplets. At each month, we define $p_{k,t}$ as the median unit value of the triplet k and estimate the following model:

$$\ln(p_{i,t}) = \alpha_i + \sum_{m=0}^{M} \beta_m \ln(e_{t-m}) + \sum_{m=0}^{M} \delta_m \ln(CPI_{i,t-m}) + X_{i,t}\gamma + \varepsilon_{i,t}, \quad (1)$$

where i indicates one triplet (i.e., postal code - augmented HS-classification - partner country) and t a month. In our baseline specification, the dependent variable, $p_{i,t}$, is the median unit value of the exported or imported triplet. The bilateral exchange rate, e_t is expressed in CHF per EUR. The EZV exchange rate does not carry any index of the destination because the focus of our analysis is on Swiss trade with the euro area. CPI_i is the CPI of the exporter country (partner country for important and Switzerland for exports). $X_{i,t}$ represents a range of control variables. These include fixed effects of each triplet, partner country - 2-digit HS specific trends and 4 quarterly GDP lags of the importer. Separate regressions are run for transactions invoiced in euro and in Swiss franc. In all specifications, we cluster standard errors at the postal code level.

Model (1) is specified in levels instead of changes because of the unbalanced nature of our panel. Many triplets are not active at consecutive

Table 1: Summary statistics

	Total sample	Pre-shock period	Post-shock period
Imports (Euro area to Switzerland)			
Based on transactions			
Unit value (log)	3.470	3.504	3.396
	(2.218)	(2.213)	(2.226)
Share invoiced in EUR	0.676	0.668	0.692
Share invoiced in CHF	0.315	0.322	0.299
Share invoiced in other	0.009	0.010	0.009
Share of available supp. unit	0.244	0.243	0.248
Based on (log) value			
Unit value (log)	3.566	3.599	3.497
	(2.464)	(2.454)	(2.481)
Share invoiced in EUR	0.708	0.699	0.726
Share invoiced in CHF	0.283	0.291	0.264
Share invoiced in other	0.010	0.010	0.010
Share of available supp. unit	0.257	0.255	0.261
Number of transactions	29 193 217	19 683 395	9 509 822
Exports (Switzerland to euro area)			
Based on transactions			
Unit value (log)	4.085	4.118	4.016
	(2.476)	(2.472)	(2.483)
Share invoiced in EUR	0.614	0.616	0.611
Share invoiced in CHF	0.371	0.369	0.375
Share invoiced in other	0.014	0.014	0.014
Share of available supp. unit	0.222	0.219	0.227
Based on (log) value			
Unit value (log)	4.223	4.252	4.167
	(2.598)	(2.594)	(2.606)
Share invoiced in EUR	0.643	0.644	0.642
Share invoiced in CHF	0.340	0.340	0.342
Share invoiced in other	0.016	0.016	0.016
Share of available supp. unit	0.236	0.235	0.240
Number of transactions	16 265 607	11 051 418	5 214 189
EZV EURCHF exchange rate	1.175	1.227	1.057
	(0.079)	(0.009)	(0.022)

Note: The table reports the mean of the mean (log) unit values. Standard deviation is shown in parenthesis when relevant. The post-shock period goes from January 16, 2015 to December 31, 2015.

months. The 2-digit HS - destination country specific trend ensures that suitable fixed effects remain when differencing equation (1).[24]

The exchange rate movement during the full sample comprise the floor period, with little exchange rate variation, the January 15, 2015, shock, and the post-floor exchange rate movements. It is clear from Figure 1 that most of the exchange rate variation is coming from the shock, and that the results of the regression are mostly representing the reaction to the shock.

Figure 4 plots the estimated β_m for m ranging from 0 (immediate pass-through) to 11 for imports (4a) and exports (4b). The red line marked with + symbols represents the accumulated pass-through for transactions invoiced in euros and the blue line with bullets those invoiced in Swiss franc.

For imports, the pass-through for euro invoiced transaction is unsurprisingly equal to 1 for the first lags and stays stable afterward. This is similar to the result uncovered in Gopinath et al. (2010) of full and stable pass-through for import transactions invoiced in the foreign currency. For exports, the immediate pass-through is not complete while the second month shows a full-pass-through. This can be attributed to a portion of declarants use the previous month's average to convert the value of their shipment into Swiss francs.[25] In the longer run, the less-than-full pass-through indicates an small underlying change in unit values expressed in euros.

For transactions invoiced in Swiss francs, the results are more surprising. The immediate pass-through of around 0.4 indicates that unit values are reacting to the exchange rate movement within the same month. Even more striking is the fact that the initial pass-through is close to the longer-run accumulated pass-through. For imports, the immediate pass-through of 0.4 is about two thirds of the longer-run pass-through of 0.65. A similarly high portion is observed for exports. This indicates that a large share of the pass-through is attained within the month of the shock rather than with delay. Furthermore, the long-run accumulated pass-through seems to be reached after the third lag only in the import case.

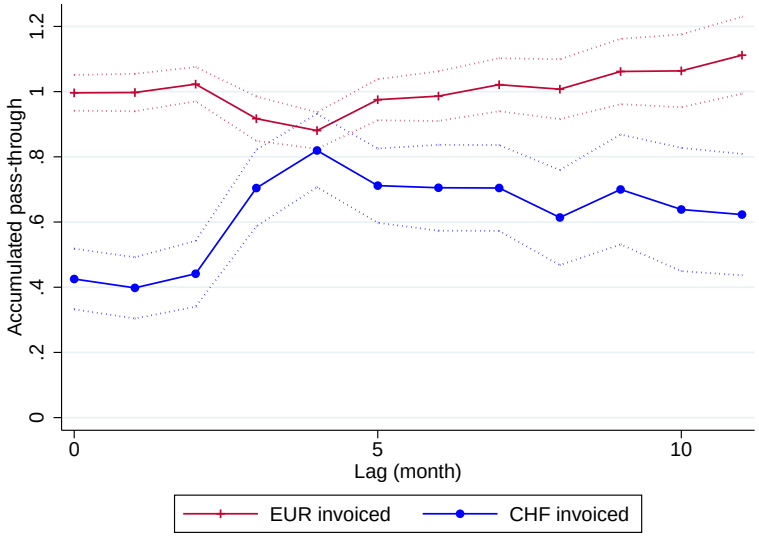
3.2 Daily estimation results

Motivated by the remarkably quick pass-through uncovered at the monthly frequency, especially for Swiss franc invoiced transactions, we next use daily data to obtain more precise estimates of the reaction to the shock. The estimation of equation (1) provides a measure of the effect of exchange rate on

[24] The regressions are conducted using the Stata module *reghdfe*, see Correia (2015).

[25] We refer the reader to the discussion on conversion procedures at the border exposed above.

(a) Imports



(b) Exports

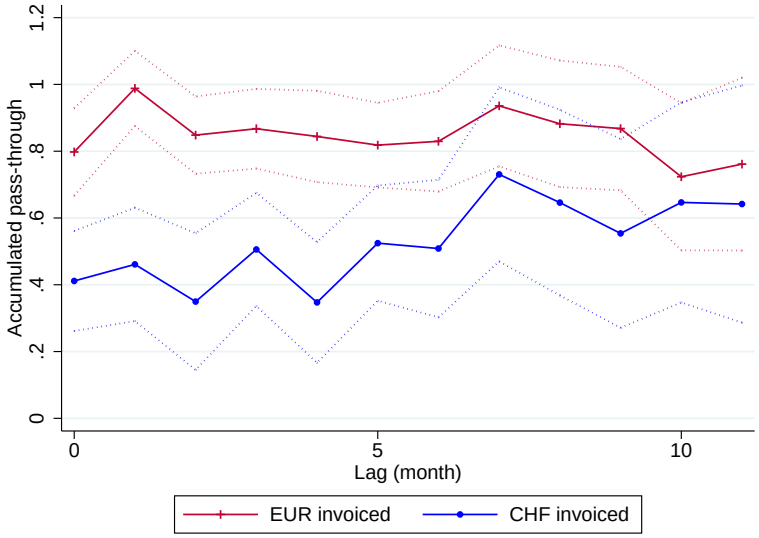


Figure 4: Accumulated pass-through on unit values based on a monthly triplet panel regression including controls for exporter's CPI and importer's GDP (specification (1)) Errors are clustered at the postal code level.

the unit values based on the whole sample. While most of the exchange rate variation in the sample comes from the January 15, 2015 shock, estimating equation (1) delivers imprecise results if the reaction to that large shock differs from reactions to small shocks. To ensure that we capture the reaction to the large shock only, we estimate an equation with daily dummies right before and after January 15, 2015. Specifically, we reduce the sample to January 2014 to June 2015 and perform an event-study analysis based on the following daily specification.

$$\ln(p_k) = \alpha_{i_k j_k s_k} + \sum_{d=-8}^{31} \beta_d^D D_k^d + \sum_{m=2}^{5} \beta_m^M M_k^m + X_k\gamma + \varepsilon_k, \qquad (2)$$

Here, k is a single transaction, p_k is the unit value, i_k is the product classification of transaction k, j_k is the partner country and s_k is the postal code. D_k^d is a daily (working day) dummy that equals one if the day of transaction k equals d and zero otherwise. We add daily dummies from the first Monday of 2015 (January 5^{th}, defined as $d = -8$ so that January 15^{th} is $d = 0$) to the last working day of February (February 27^{th}, $d = 31$). The dummies before January 15 capture a potential anticipation of the shock's effect on unit value, while the ones after capture the daily evolution of the level of unit values after the shock. M_k^m are monthly dummies from March 2015 to June 2015, taking value 1 is the transaction k happens within the month m and 0 otherwise. They capture the monthly level in unit values after the period covered by daily dummies. X_k represents the controls including a set of country - HS2 specific monthly trends. We treat weekend transactions as if they take place on Fridays.[26]

We stress that the model specified in (2) reflects our aim to exploit the variation of the large exchange rate shock of January 15, 2015, and to estimate the subsequent reaction of unit values on a fine resolution of the time dimension. Specifically, the use of daily dummies ensures that only changes of unit value on a specific day are captured, which can then be related to the corresponding exchange rate movements. The high frequency of dummies in equation (2) enables us to interpret the coefficient of the daily dummies close in time to the shock as capturing the shock's effect: as argued in section 2.1, the absence of significant exchange rate changes before the shock ensures that no lagged exchange rate movement contaminates our estimation in the days following the shock. Other price determinants such as

[26]Weekend transactions represent 3.07% of the number of transactions (Saturday is 2.5%, Sunday is 0.57%), and 1.71% of total value (1.49% for Saturday and 0.22% for Sunday).

marginal costs are also unlikely to change in the few weeks after the shock. The downside of this specification is that it is less readily comparable with standard specifications that rely on exchange rate lags as the one defined in equation (1). Specifically, we cannot exclude the possibility that exchange rate movements after the shock are influencing unit values in periods further away from the shock, so that the value of monthly dummies for March to June only give an imprecise estimate of the effect of the shock. The standard models, however, produce estimated coefficients that rely on the exchange rate variation of the whole period, which is not the aim of our study.

Based on the daily estimation, we also provide measures of start and end of the pass-through, which then give rise to the definition of the speed of pass-though (and thus justify the present paper's title). For transactions invoiced in Swiss francs, the start of the adjustment is defined as the first day for which the accumulated change in unit values (the estimated β_d^D in (2)) is different from the pre-shock daily dummies average. The end of the adjustment is defined as the first day for which the daily dummy is different from the pre-shock average and the ratio between the accumulated change in unit value and the accumulated change in the exchange rate is not significantly different from the medium-run pass-through ratio, which is defined as the average of the last four monthly pass-through ratios. When the medium-run pass-through is not different from 0 in the Swiss franc, we define no start nor end of adjustment.[27] Given the little reaction in unit value expressed in euros, we do not define start nor end day of adjustment for transactions invoiced in euros.

For expositional purposes, our estimates corresponding to daily transactions are given a graphical representation using plots of the daily coefficients for euro and Swiss franc invoiced transactions together with their 95% confidence intervals. The medium-run (monthly) estimates are included in these plots. Their coefficients are denoted as circles with 95% confidence inter-

[27] Formally, we first define the pre-shock level as the average of the coefficient on dummies D_{-9} to D_0 ($PRE = \frac{1}{10}\sum_{i=-9}^{0}\beta_i^D$), and, for each daily or monthly dummy, we define a "pass-through" ratio $PT_d = \frac{\beta_d^D - PRE}{\hat{E}_d}$, where $\hat{E}_d$ is the accumulated change in the exchange rate from January 15^{th} to day or month d. d_{start} is such that the null hypothesis $PT_{d_{start}} = 0$ is rejected and $PT_i = 0$ is not rejected for all $0 < i < d_{start}$. d_{end} is such that the null hypothesis $PT_{d_{end}} = \frac{1}{4}\sum_m PT_m$ where m covers all months after the daily dummies, namely March to June 2015, is not rejected, although $PT_{d_{end}} = 0$ is rejected. A shortcoming of this approach is that the wider the standard errors of our estimates are, the easiest it is to not reject equality with the medium-run. To attenuate this, we require the end day pass-through not to be significantly different from the medium-run at the 10% level instead of the usual 5% level.

vals.[28] Vertical dashed and dotted lines indicate the *start* and *end* day of adjustment when relevant. The accumulated change in the exchange rate relative to January 15^{th} pre-shock level is also shown in a blue dashed line.

Figure 5 illustrates the exchange rate pass-through into unit values of imports. The top panel corresponds to imports invoiced in euros, documenting an immediate and mechanical effect of the exchange rate shock on unit values. The daily dummies closely follow the exchange rate and indicate a complete pass-through as well as little nominal price adjustment in the period covered by daily and monthly dummies.[29]

The fast pass-through of imports invoiced in euros is not surprising. More striking is the fast responses of unit values of import invoiced in Swiss francs, illustrated in the lower panel of Figure 5. We say the pass-through is *fast* in the sense that the start day and end day lie within a short period after the shock. Already two working days after the shock, unit values drop significantly, as much as a fraction of 0.32 of the exchange rate change. After eight working days, the pass-through is about 0.5 and is not statistically different from the 0.6 average pass-through of the last four months of the sample (to which we refer to as medium-run pass-through). Our interpretation of these results is that the usual less-than full medium-run pass-through materializes at an exceptionally fast speed.

Figure 6 shows that unit values for exports behave slightly differently. The euro invoiced exports do not show the expected full and instantaneous mechanical adjustment. We attribute this finding to accounting differences. A portion of exporting firms do not use the daily exchange rate in their customs declaration, but rather the previous month average or their internal accounting exchange rate.[30] The daily dummies in February are much closer to the exchange rate than those in January, a result consistent with the use of the updated monthly rate of January for February transactions. This feature also prevents us from defining a start and end day of adjustment in the case of euro-invoiced exports, as the coefficients of January dummies cannot be interpreted as changes in underlying unit values, even though the monthly dummies at the end of the sample seem to indicate a partial medium-run pass-through of about 0.94.

The interpretation of estimates based on transactions invoiced in Swiss

[28] The values are rescaled by the average of the pre-shock dummies coefficient, so that the y-axis values can be interpreted as the average change in unit values since the shock.

[29] One exception to full pass-through occurs on the first day after the shock (January 16^{th}). The deviation is explained by the fact that the (one-day lag in the) official exchange rate had not yet adjusted to the shock.

[30] Recall, this accounting practice is not permitted for imported goods.

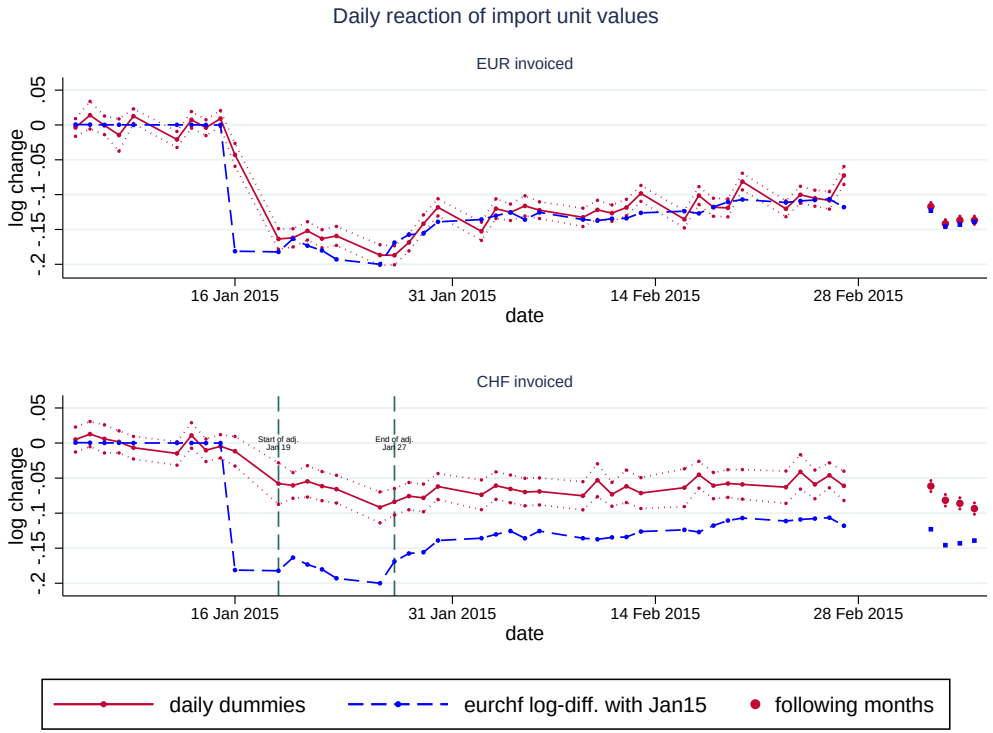


Figure 5: Daily dummies for import unit values (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a 2-digit HS-country specific trend. Errors are clustered at the postal code level.

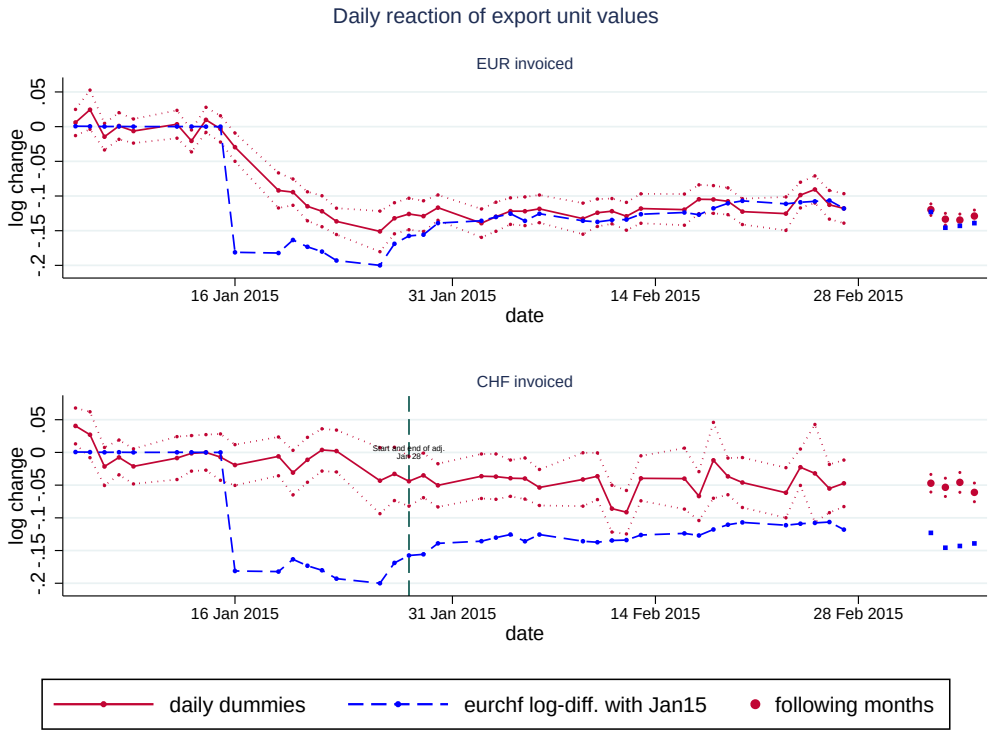


Figure 6: Daily dummies for export unit values (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a 2-digit HS-country specific trend. Errors are clustered at the postal code level.

franc is simpler, since these are not converted by any exchange rate. Figure 6 shows that exports invoiced in Swiss francs experience a drop in their unit values of about 5% (or a pass-through of 0.28; see Table 2 reporting the start/end day and medium-run pass-through estimates) after about eleven working days, a value not significantly different from the medium-run pass-through of 0.31.

The clear difference of the exchange rate pass-through across groups by invoicing currencies is very much in line with the findings of the recent literature. In particular, the (almost) complete pass-through into unit values of euro-invoiced transactions corresponds to the findings in Gopinath et al. (2010), who shows that the exchange rate pass-through into U.S. import prices is complete for non-USD invoiced imports. Gopinath (2015) generalizes this point, writing that "international prices, in their currency of invoicing, are not very sensitive to exchange rates at horizons of up to two years" and that "a good proxy for the sensitivity of a country's traded goods inflation to exchange rates is the fraction of its imports invoiced in a foreign currency." Accordingly, the top panel of Figure 5 documents complete pass-through of exchange rate shocks into import prices for euro-invoiced imports. These observations strongly suggest that nominal prices, expressed in the invoicing currency, did not react systematically to pass through the exchange rate shock into border prices.

Quite contrary, the bottom panels of Figures 5 and 6 show a non-negligible short-run pass-through of the exchange rate shock for transactions invoiced in Swiss francs. We interpret this central result as evidence that nominal prices did adjust fast and systematically to pass through the exchange rate shock into border prices.[31] We acknowledge that we need to argue very carefully when inferring (unobserved) price changes from the pass-through into unit values. In particular, three important factors complicate our interpretation of changes in unit values as price changes, potentially induce changes in unit values and creating estimation biases. These factors are quality shifts within product classifications, exit from and entry to foreign markets by firms or products and, to some extent, firm heterogeneity.

Quality shifts within product categories constitute a fundamental problem when inferring price changes from unit values. We argue, however, that they are unlikely to drive the drop in unit values shown in the bottom panels of Figures 5 and 6. We corroborate this view by looking at the sign of potential biases that would result from a quality shift. We first observe

[31] We do not take a stance on why unit values of Swiss franc-invoiced transactions did display a pass-through, although those of euro-invoiced transactions did not.

that, following the exchange rate shock, Swiss consumers can be expected to substitute towards higher quality in the basket of imported foreign goods, which now become cheaper. Such an effect, however, would *increase* import unit values, although the average unit value did actually *decrease* (see Figure 5). Any substitution effect should thus attenuate the estimated drop of unit values of Swiss imports. Further, the same bias should affect estimates of pass-through into export unit values in the opposite way: foreigners, for whom prices of Swiss products become more expensive, should substitute towards lower quality, which would generate a drop in unit values after the exchange rate shock. If that effect were strong, the estimated drop of unit values in the bottom panel of Figure 6 would be amplified. Yet, when comparing the pass-through into unit values of imports and exports, the former are relatively large compared to the latter, although biases due to quality shifts would induce the opposite image. This comparison suggests that quality substitution is rather limited. Finally, we point out that the unit values of imports that are invoiced in euros (top panel of Figures 5 and 6) remained very stable.[32] Again, this observation indicates that strong substitution effects are not affecting this set of transactions.

Exit and entry of firms or products into foreign markets is a second source of potential bias of pass-through estimations. Gagnon et al. (2014) argue that exit into and entry from export markets may induce an attenuation bias in the pass-through estimations. In the presence of such an attenuation bias, however, the true pass-through would be even larger than our estimated changes in unit values for Swiss franc-invoiced goods. Gagnon et al. (2014) also report that empirically the "biases are modest over typical forecast horizons" and even less so for our short period of two weeks.

Nevertheless, we try to address potential biases due to exit and entry. We gauge the exit and entry rate around the date of the exchange rate shock by looking at entry and exit of pairs of product and partner country.[33] Specifically, for each week, w, we compute the number of those product-country pairs with positive exports (imports) within the two weeks, w and $w+1$.[34] Out of these sets of product-country pairs, we compute the share with zero exports (imports) in the calendar year before w. This share of

[32] Notice that no bias due to substitution effects can be expected for the Swiss export basket, since euro prices remained unchanged as the top panel of Figure 6 shows.

[33] We recognize that, by looking at exits and entries of these pairs, we cannot observe all product exits and entries but a subset of them. Indeed, any exiting (entry) of a pair must reflect at least one product exit (entry) from the market in question, although the reverse is not true.

[34] The time span of two weeks reflects the period, in which the unit values react.

entrants is plotted in the top panel of Figure 7 for exports (fat solid line) and for imports (fat dashed line). Also, corresponding thin solid and dashed lines are added as references for the same period of the preceding year. We observe that the figure does not reveal unusual entry dynamics around the date of the shock (indicated by the vertical line) in terms of levels or relative to the previous year.

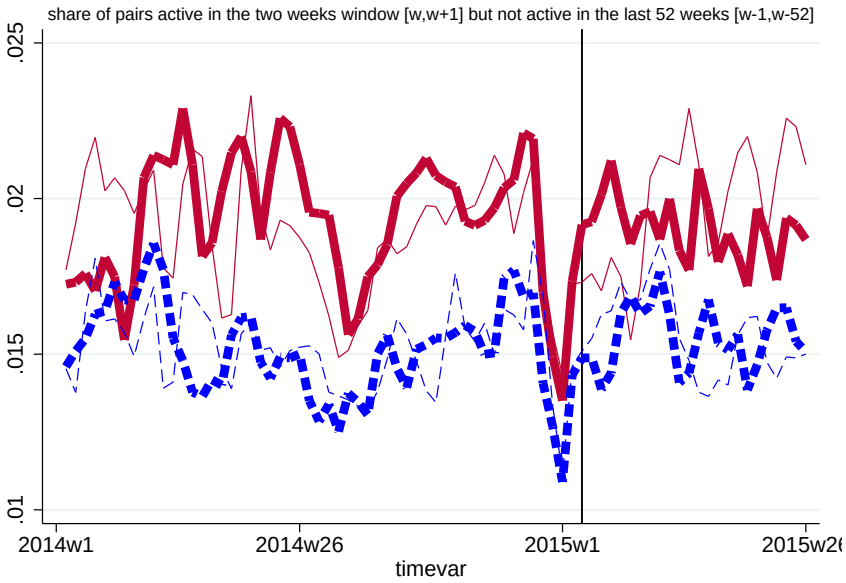
Similarly, for each week w we look at the number of those pairs with positive exports (imports) within the calendar year preceding w. Out of these pairs, we compute the share with zero exports (imports) in the two weeks, w and $w+1$. This share of *temporary exiting pairs* is plotted in the bottom panel of Figure 7 for exports (fat line) and for imports (fat dashed line). Corresponding thin solid and dashed lines are added as references for the preceding year. Again, the figure does not indicate unusual exits around the date of the shock.

Clearly, we cannot observe all exits and entries of firms or products. Yet, the set of exits and entrants that can be identified (those plotted in Figure 7) do not indicate that unusual entrance or exit happen in the period after the shock within which the adjustment takes place.

Having discussed the potential effects of the most relevant biases of exchange rate pass-through into unit values, we conclude that a large part of the sharp and sudden fall in the unit values in the immediate aftermath of the exchange rate shock must have been driven by underlying price changes. Of course, this does not imply that the price adjustments were identical in magnitude for all firms or products. Indeed, it is well known that there is heterogeneous pass-through across firms. For example, Berman et al. (2012) show that highly productive firms display relatively low import price exchange rate pass-through while Amiti and Weinstein (2011) show that import-intensive exporters display relatively low export price pass-through. Indeed, some firms might have adjusted their price one-to-one with the exchange rate, although others did not adjust prices at all. Consequently, we read our estimation results as follows. Most firms that adjusted prices in reaction to the exchange rate shock did so within the very short period of two weeks after the shock did occur. Put differently, if a firms optimal response to the exchange rate shock was to change its border price, this price change was implemented very quickly.

These observations suggest that the fast exchange rate pass-though identified in our econometric analyses stems from underlying nominal price changes. In particular, we read our findings as strong evidence of a prompt price adjustment in response to a large shock to the Swiss franc on January

(a) Entry shares



(b) Exit shares

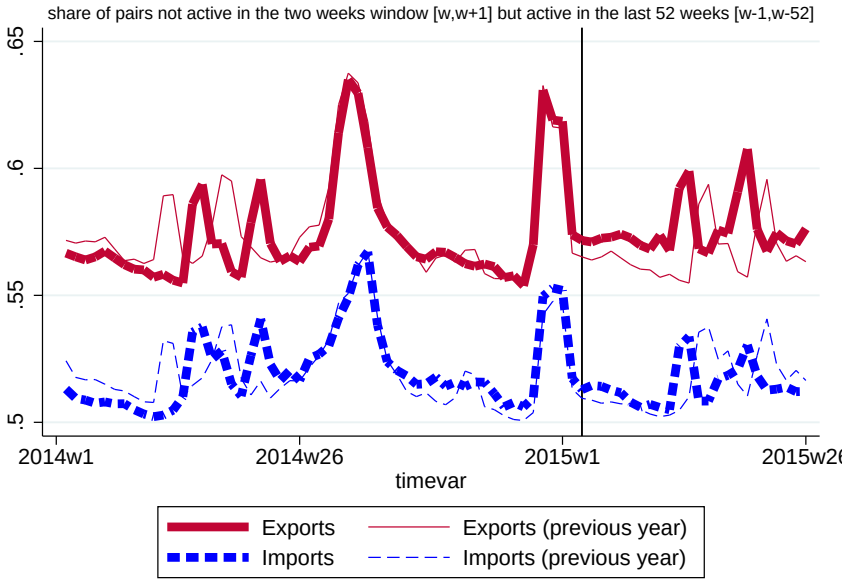


Figure 7: Entry and (temporary) exit shares at the weekly frequency

15, 2015.[35] We claim that the price adjustment is clustered in that an uncommonly high share of firms adjust their prices. This adjustment, which is conditional on price adjustment in the medium run takes place within the first two weeks after the shock. Presuming conservatively that prices are either not adjusted at all or one-to-one with exchange rates, then about 50% of all import prices invoiced in Swiss francs must have been adjusted after eight working days (see Table 2). Since 61% are adjusted in the medium-run, this would mean that a fraction of 0.82 of all firms that ultimately adjusted their prices did so promptly. Existing measures of average duration between price adjustment usually range at values larger than four months, which roughly translates into 4% within eight working days.[36] When compared to these values, the conservative estimates of 50% share of import price adjustments is very large.

Our interpretation of prompt price adjustments, in turn, implies that nominal rigidities play a minor role for the period immediately following the exchange rate shock. The findings reported above thus constitute strong evidence in favor of state-dependent pricing frameworks à la Dotsey et al. (1999) and Golosov and Lucas (2007). We also observe that our findings are hard to explain by pricing models based on *sticky information* à la Mankiw and Reis (2002). In particular, an economy in which a constant fraction of agents updates information and pricing plans within each period does not simultaneously match the frequency of price adjustments in normal times and the large fraction of price adjustments immediately following the unanticipated exchange rate shock. Our work thus highlights that exceptional price responses to shocks that are particularly visible or hard to ignore are not captured by sticky information models. Instead, our findings complement Nakamura and Steinsson (2008), who provide evidence in favor of menu costs by emphasizing the importance of idiosyncratic shocks as a driving force of price changes.

Finally, we also notice that our findings differ somewhat from those in

[35] We also acknowledge that we are unable to directly measure price stickiness, as Gopinath and Rigobon (2008), who track the frequency of price adjustments. We thus cannot follow Gopinath et al. (2010), who estimate the exchange rate pass-through conditional on price adjustments.

[36] The median frequency of nominal price adjustments reported in Gopinath and Rigobon (2008) is 10.6 (12.8) months for U.S. imports (exports). Kaufmann (2009) reports that 13,8% of prices in the Swiss CPI basket are adjusted within a quarter between 2000 and 2005, i.e. at a median duration between price changes of 4.6 quarters, or more than a year. Bils and Klenow (2004) reports the much lower value of 4.3 months medium duration for U.S. prices. Lein (2010) reports survey data of Swiss firms, that between 1999 and 2007, only 34% of firms surveyed have changed their prices in the previous quarter.

earlier work by Gopinath and Rigobon (2008) who document that price adjustments of U.S. import prices in episodes of large exchange rate devaluations were qualitatively "as expected, but [...] surprisingly weak."[37] Part of this mild reaction may be explained by the fact that the exchange rate devaluations were anticipated, so that some prices were adjusted in advance of the devaluation, which dampened the reaction on impact (see the according Figure II in Gopinath and Rigobon (2008)). Moreover, most devaluation episodes concern developing countries for which trade is typically invoiced in U.S. dollars and thus display low pass-through rates even in the long run (see Gopinath et al. (2010)).[38] Thus, the fact that our work uncovers strong reactions by comparison may be traced back to the unusually clean and unanticipated exchange rate shock on January 15, 2015, as well as the substantial differences in invoicing practices between the U.S. and Switzerland.

Overall, our results suggest a fast adjustment process of nominal prices. Therefore, nominal rigidities seem to have little importance in the face of such a big shock, as import unit values show a fast and persistent pass-through. On the export side, the fast reaction of Swiss franc invoiced unit values is also striking: a significant price adjustment already takes place before the end of January, that is within 11 working days.

A question that remains open so far is how the fast adjustment of export and import prices came about in practice. After all, contracts and physical delivery of cross-border transactions are typically understood to have substantial time-lags, very often exceeding the two weeks of inferred price adjustments.[39] In an attempt to address this question, we turn to informal information obtained through interviews conducted by delegates of the SNB regional network.[40] The interviews revealed that Swiss managers did

[37]The frequency of monthly import price increases (decreases) is shown to fall (rise) by about 5 percentage points, although the average unconditional price change drops by about -0.5% in the month after the exchange rate devaluation.

[38]Figure II in Gopinath and Rigobon (2008) suggests an accumulated average import price drop around large devaluations of about 2%, which, given an original shock of 15%, amounts to a pass-through rate of 0.13. This is in the realm of the 24-months pass-through rate of 0.17 reported for dollar invoiced transactions in Gopinath et al. (2010).

[39]See Amiti and Weinstein (2011).

[40]The SNB delegates conduct quarterly interviews with about 230 managers and entrepreneurs on the current and future economic situation of their companies and on the Swiss economy in general. The selection of companies differs from one quarter to the next. It reflects the industrial structure of the Swiss economy, based on the composition of GDP. The survey's main results are reported in the SNB's Quarterly Bulletin. See SNB (2015) for example.

take unconventional measures to adjust to the appreciation of the franc. Established contracts between Swiss importers and international distributors were immediately renegotiated after the shock to maintain the client base. In several cases, prices were reset automatically, as some contracts contain a built-in clause according to which prices are reset whenever exchange rate changes exceed certain thresholds. The motive behind this practice is to share the impact of exchange rate changes between parties.

For exporters, the mirror image emerged. Based on the experiences of the Swiss franc shock in 2011, there was the general recognition that an immediate price reduction of Swiss exports was needed. Some exporting companies whose bargaining position was too weak (e.g., because of strong competition) absorbed the total cost of the price reduction to defend market-shares. In some cases, prices were even renegotiated for goods that were purchased before the shock but whose delivery was still outstanding because of delivery lags. Again, this adjustment was done to maintain the client base. The informal information thus complements and reinforces our main message in suggesting that reactions to the exchange rate shock were unusually fast.

4 Robustness checks

This section presents a series of robustness checks on the previous section's main finding that the speed of price adjustment to a large exchange rate shock is remarkably fast. Since our main attention concerns the start and the end day of the exchange rate pass through, and since, moreover, these dates can only be sensibly defined for transactions that are invoiced in Swiss francs, our robustness checks are limited to this subset of observations. In other words, we investigate the robustness of our results presented in the bottom panels of Figures 5 and 6.

We present different cuts of the data with the aim to address concerns related to our data limitations but also to the potential critique of the role of firm-specific and product-specific determinants of exchange rate pass-through.

All of these robustness checks are based on specification (2) and they are summarized in Table 2. The corresponding graphs of the daily price dynamics are relegated to the Appendix 2. To facilitate a convenient comparison, we also include the relevant statistics of our baseline regression in this table.

4.1 Unit values versus unit prices

A common critique of analyses based on unit values is these measures constitute not only imprecise but potentially biased proxy of actual prices. To address related concerns, we restrict the sample to those products and observations for which information on 'supplementary units' are available. These units represent the economically relevant accounting measure for the goods. Typical units are "pairs" (e.g., for shoes), "pieces" (e.g., for watches).[41] The resulting measures, which we label *unit prices*, are again imperfect but constitute arguably better measures of prices.

The start and end date for unit prices are listed under the section "Sup. units" in Table 2. Compared to the baseline regression, the estimations based on unit prices reveal a comparable speed of the pass-through. Specifically, the differences range within the time-frame of two weeks, which confirms the view that price adjustments are fast. For example, the upper panel of Table 2 presenting the results for Swiss franc-invoiced imports shows that the baseline regression for imports invoiced in Swiss francs (row E.1) results in a statistically significant pass-through of 0.32 after two working days and a medium-run pass-through of 0.58 attained after 8 working days. The corresponding estimates based on unit prices (row E.1b) show a similar start day and imply that the medium-run pass-through is reached after 7 working days. It is clear that the adjustment starts early in both cases and that the pass-through reaches its medium-run value in less than two weeks.

4.2 Proxying firm size

Our second set of robustness checks aims at addressing the impact of firm size on the estimations. Berman et al. (2012) show that high productive firms have a higher (lower) pass-through into export (import) prices, as they adjust their markups more in response to exchange rate shocks. In turn, Amiti et al. (2014) show that import intensive exporters have a lower exchange rate pass-through into their export price, and thus a higher exchange rate pass-through into the import prices. It might be the case that the speed of response to the shock also differs for each type of exporters. Although we cannot control for import intensity or productivity, we can restrict our sample to exclude a large share of small importers or small exporters.

[41] For example, while declarations for some motor parts only have information on the mass instead of the number of parts, declarations for watches have the more precise information of the number of units.

Based on this rationale, we first restrict the export's transactions sample to the biggest combinations of postal code and 8-digit HS code that make up two-thirds of the total export value. We argue that this restriction, shown as row E.2 in Table 2, excludes many of the small and medium sized exporter firms and is likely to contain big exporter firms at the same time. We also restrict the import transactions sample to the largest combination of partner country and 8-digit HS code. While this restriction, shown as raw I.2, is less precise than the one for imports, it still excludes many small foreign firms exporting to Switzerland from the sample. The restriction shows little variation in the pass-through into import unit values for big exporters, but a slightly lower pass-through into export unit values, consistent with Amiti et al. (2014). With respect to the speed of the reaction, however, the big exporters subsample still exhibit fast adjustment.[42]

To control for the size of the importing firm, we restrict the import's transactions sample to the biggest combination of postal code and 8-digit HS code, and restrict the exporter's sample to the biggest combination of isocode and 8-digit HS code. We list the results in row I.3 and E.3 in Table 2. The medium-run pass-through into import unit values decreases substantially for big importers, while the pass-through into export unit values increases slightly.[43]

A different and additional way to proxy for firm size is by separating transactions of large value from transactions of low value.[44] We adopt the value of CHF 300 as a threshold to define roughly similarly sized subsamples of small value shipments and of large value shipments.[45] Rows I.4 and I.5 in Table 2 show that the medium-run pass-through into import unit values is lower for big shipments and higher for small ones. Regarding the pass-through into export unit values (rows E.4 and E.5), the pattern is not confirmed but the estimated medium-run pass-through of both subsamples lies very close together between 0.36 and 0.39. The estimations also show that, again, no notable differences are observed for the start and end dates.

[42] In Appendix 2, Figures 9 and 10 shows the daily results for respectively imports from big exporters and export of big exporters.

[43] In Appendix 2, Figures 11 and 12 shows the daily results for respectively imports of big importers and export to big importers.

[44] Kropf and Sauré (2014) show that large and productive exporters tend to make shipments of higher values.

[45] Swiss Custom Administration adds a value added tax on imports worth more than CHF 300. Our results are not sensitive to this threshold. In Appendix 2, Figure 13 (15) shows the daily results for the import (export) unit values of transactions of less than CHF 300. Figure 14 (16) shows the daily results for the import (export) unit values of transactions of more than CHF 300.

4.3 Intermediate, investment and consumption goods

One of the limitations of our data implies that intrafirm transactions remain unidentified. This drawback may be of importance for the rate of pass-through. For the United States, Neiman (2010) documents that prices of intrafirm cross-border trade display less stickiness. However, the shape of the accumulated pass-through reported in Neiman (2010) displays a similar lack of immediate adjustment for both intrafirm and arm's length transactions. Nevertheless, it might still be feared that our fast adjustment results from multinational firms quickly adjusting their transfer prices.[46] Concerns related to intrafirm trade are partially addressed by our robustness checks above, where we have shown that small transactions (those that presumably correspond to small and medium sizes firms or to individuals) do not reveal a substantially different speed of exchange rate pass-through.

In addition to the robustness checks above, we also address concerns about intrafirm trade by looking at different good categories: consumption goods, investment goods and raw materials, and intermediate goods.[47] Restrictions 6, 7 and 8 in Table 2 show the start and end days with the pass-through estimates for consumption (row 6), investment goods and raw materials (row 7), and intermediate goods (row 8).[48] Some heterogeneity in the medium-run level of pass-through is uncovered, but again, the results for exports and imports show that the adjustment starts rapidly and reaches its medium-run pass-through estimate within 10 days after the shock.

Assuming that the share of intrafirm trade is different across the main categories, this indicates that intrafirm transactions do not drive our fast pass-through result.

4.4 Differentiated, referenced, and homogeneous goods

With respect to price adjustment, the organization of the market plays a significant role. Using Rauch (1999)'s classification, Gopinath and Rigobon (2008) report that the median import price duration is substantially longer

[46] Even in that case, however, the fast adjustment implied by our results would indicate a faster reaction of multinational firms than usual.

[47] The Swiss customs office classifies each 8-digit HS code as either consumption good, raw material, investment good, energy good, or cultural good. We perform our analysis on consumption and raw material and investment goods separately, keeping only those transactions whose HS code is classified in a unique category. We use the Broad Economic Categories (BEC) classification to identify intermediate goods.

[48] In Appendix 2, Figure 18 (21) shows the daily estimates on import (export) unit values for the investment goods and raw material, Figure 17 (20) presents those for consumption goods and Figure 19 (22) those for intermediate goods.

for differentiated goods (14.2 months) than for reference goods (3.3 months) and goods in the organized exchange category (1.2 months). To check that the fast pass-through is not driven by the organized exchange or the reference goods, we run the daily regression on each category separately.[49] The results, presented in rows 9 to 11 in Table 2, show that the level of pass-through differs for each category. Consistent with intuition, goods traded on an organized exchange show a higher pass-through, followed by reference priced goods and differentiated goods. Still, the reaction is fast in all three categories. Even differentiated goods show a reaction after the second (third) working day for imports (exports) unit values and reach their medium-term level after 8 (11) working days.[50]

4.5 Precision of currency recording

In our description of the Swiss customs data, we have pointed at the possibility that the invoicing currency may be misreported for some transactions. Specifically, each customs declaration has a unique invoicing currency but may contain multiple transactions. In such cases, the invoicing currency of the main transactions is recorded. This practice may induce biased estimates, as transactions that are recorded as invoiced in Swiss francs may actually be invoiced in euros. Consequently, the reaction of unit values of transactions invoiced in Swiss francs may be overestimated (and similarly the reaction of unit values of transactions invoiced in euros underestimated). The fact that the euro-invoiced transactions follow the exchange rate change almost perfectly in Figure 5 already indicates that the misclassification does not severely affect our results for euro-invoiced transactions. To formally control for a potential bias, we run the same regressions although restricting the sample to transactions for which a misclassified invoicing currency can be excluded. We do so by focussing on customs declaration with a single transaction only. The results are listed as restriction I.9 and E.9 in Table 2. Consistent with some currency misclassification, they show a lower pass-through that the full sample. They show however that the speed of adjustment is fast even in those cases were currency misclassification is impossible, as the medium-run pass-through is reached after only a few days

[49] Due to a lack of sufficient observations, we only regress unit values and are unable to further reduce the sample to transactions where unit prices are available.

[50] In Appendix 2, Figure 23 (24) shows the daily estimates on import (export) unit values. It is notable that the exclusion of the more volatile organized exchange and reference categories lead to more precise estimates of the daily reaction.

in both cases.[51]

4.6 Product category regressions

Finally, we investigate whether the speed of price adjustment differs across HS categories by running separate regressions for each HS section. Tables (3) and (4) present the section specific results respectively for imports and exports. The results show substantial heterogeneity in the medium-run pass-through, with some categories showing no significant medium-run pass-through and other displaying full-pass-through.

Whenever the pass-through is nontrivial, however, the medium-run pass-through is reached within a short time window.[52]

5 Conclusion

This paper is the first to analyze the speed of exchange rate pass-through for tradable goods to an unusually large exchange rate shock at the daily frequency. The narrow event window ensures that the documented adjustment is in response to an exchange rate shock and not to other information. This high frequency setup allows us to precisely track the dynamics of pass-through. The exogenous shock originates from the SNB's decision to lift the minimum exchange rate policy, which resulted in a permanent appreciation of the Swiss franc of more than 11% against the euro. Our estimates indicate that the pass-through begins two working days after the lifting of the minimum exchange rate and reaches on average it's medium-run pass-through after eight working days. Although the rate of pass-through may not be uniform across various subsets of transactions and product groups, we show that the timing of the adjustment is homogenous.

We argue that our pass-through results constitute strong evidence in favor of fast nominal price adjustment and the fact that an uncommonly large share of firms adjust their prices immediately after the Swiss franc shock. As such, our results have two important implications. First in modeling price setting behavior, the fast adjustment of prices suggests that nominal rigidities play only a minor role in the face of large exchange rate shocks. These considerations lead us to adopt the view that international firms demonstrate a high level of flexibility in their ability to respond to large sudden changes in

[51] In Appendix 2, Figure 25 (26) show the daily results for transactions where currency misclassification is not possible for imports (exports).

[52] In Appendix 2, Figure 27 (28) shows the median of the section specific daily point estimates and confidence intervals for imports (exports).

Table 2: Daily regression results (specification 2) for CHF invoiced transactions

Imports	Sample	Start day	End day	Start day PT	End day PT	Med-run PT	Observations
All obs.	I.1) baseline	2	8	0.317	0.496	0.611	8608987
	I.2) big exp.	3	8	0.312	0.495	0.612	3362122
	I.3) big imp.	11	11	0.291	0.291	0.373	1479497
	I.4) value $>$ 300	3	12	0.182	0.262	0.410	3306882
	I.5) value $<$ 300	2	7	0.370	0.604	0.722	5164283
	I.6) consump. goods	2	7	0.495	0.645	0.737	4489635
	I.7) invest. goods	5	8	0.259	0.375	0.475	4086848
	I.8) interm. goods	2	6	0.288	0.419	0.592	1846683
	I.9) diff. goods	2	8	0.301	0.510	0.596	7699835
	I.10) ref. priced	2	5	0.275	0.530	0.634	614535
	I.11) org. exchange	5	7	0.454	0.609	0.919	53826
	I.12) single trans.	2	2	0.470	0.470	0.508	2165627
Sup. units	I.1b) baseline	2	9	0.381	0.621	0.580	2274015
	I.2b) big exp.	2	2	0.328	0.328	0.510	975937
	I.3b) big imp.	10	14	-0.318	0.334	0.476	516469
	I.4b) value $>$ 300	4	12	0.222	0.314	0.379	1062995
	I.5b) value $<$ 300	2	7	0.471	0.545	0.755	1165622
	I.6b) consump. goods	2	9	0.592	0.639	0.809	1437471
	I.7b) invest. goods	6	6	0.421	0.421	0.208	813982
	I.8b) interm. goods	1	1	0.437	0.437	0.483	224350
	I.12b) single trans.	2	2	0.361	0.361	0.421	656835
Exports	Sample	Start day	End day	Start day PT	End day PT	Med-run PT	Observations
All obs.	E.1) baseline	9	9	0.280	0.280	0.375	5865132
	E.2) big exp.	10	10	0.426	0.426	0.339	783764
	E.3) big imp.	3	3	0.275	0.275	0.408	1169410
	E.4) value $>$ 300	7	7	0.213	0.213	0.359	2636574
	E.5) value $<$ 300	8	8	0.352	0.352	0.398	3192973
	E.6) consump. goods	3	10	0.317	0.448	0.515	2052081
	E.7) invest. goods	9	9	0.374	0.374	0.314	3801049
	E.8) interm. goods	10	10	0.293	0.293	0.373	1345218
	E.9) diff. goods	3	11	0.136	0.320	0.377	5232046
	E.10) ref. priced	2	2	0.328	0.328	0.414	371629
	E.11) org. exchange	9	9	0.623	0.623	0.969	50760
	E.12) single trans.	3	3	0.281	0.281	0.246	1160021
Sup. units	E.1b) baseline	12	12	0.602	0.602	0.505	1588210
	E.2b) big exp.	12	13	0.886	0.637	0.515	287431
	E.3b) big imp.	12	12	0.747	0.747	0.618	369269
	E.4b) value $>$ 300	12	12	0.557	0.557	0.440	882131
	E.5b) value $<$ 300	9	12	0.272	0.613	0.568	696429
	E.6b) consump. goods	3	3	0.427	0.427	0.617	1041828
	E.7b) invest. goods	14	14	0.687	0.687	0.303	540259
	E.8b) interm. goods	.	.	.	.	0.289+	113065
	E.12b) single trans.	5	5	0.555	0.555	0.376	210603

All regressions include augmented 8 digits HS code - country - postal code fixed effects and a 2 digits HS code-country specific trend.
Errors are clustered at the postal code level. Start day represent the first day where the pass-through is significantly different from 0.
End day represent the first day where the pass-through is different from 0 and not different from the medium-run pass-through.
+ indicates that the medium run pass-through is not significant at the 5% level.

Table 3: Imports daily regression results (CHF invoiced, by HS section)

	Start day	End day	Start day PT	End day PT	Med-run PT	Observations
Live animal; animal pro~s	4	4	0.592	0.592	0.686	35222
Vegetable products	2	2	0.326	0.326	0.488	300601
Animal or vegetable fat~l	7	7	0.707	0.707	0.895	9544
Prepared foodstuff; bev~s	2	3	0.337	0.632	0.690	769461
Mineral products	.	.	.	.	-0.071+	73756
Products of the chemica~i	4	4	0.501	0.501	0.584	686242
Plastics and articles t~r	2	10	0.519	0.629	0.976	577900
Raw hides and skins le~u	1	1	0.647	0.647	1.020	142156
Wood and articles of wo~	8	8	0.896	0.896	1.208	75043
Pulp of wood or of othe~s	2	2	0.506	0.506	0.537	626366
Textiles and textiles a~s	2	2	0.677	0.677	0.701	937727
Footwear headgear umb~s	1	2	0.549	0.841	1.166	196529
Articles of stone plas~e	4	5	0.348	0.570	0.830	222691
Natural or cultured pea~c	2	6	3.859	1.525	2.219	51872
Base metals and article~e	3	8	0.374	0.677	0.693	682903
Machinery and mechanica~a	6	8	0.255	0.337	0.391	1579390
Vehicle aircraft vess~a	.	.	.	.	0.205+	709585
Optical photographic ~g	4	4	0.413	0.413	0.435	432077
Arms and ammunition; pa~a	.	.	.	.	-0.625+	675
Miscellaneous manufactu~c	2	3	0.358	0.603	0.887	499247

All regressions include augmented 8 digits HS code - country - postal code fixed effects and a 2 digits HS code-country specific trend.
Errors are clustered at the postal code level. The start day represent the first day where the pass-through is different from 0.
The end day represent the first day where the pass-through is different from 0 and not different from the medium-run pass-through.
+ indicates that the medium run pass-through is not significant at the 5% level.

Table 4: Exports daily regression results (CHF invoiced, by HS section)

	Start day	End day	Start day PT	End day PT	Med-run PT	Observations
Live animal; animal pro~s	1	10	0.153	0.482	0.568	73616
Vegetable products	14	14	1.265	1.265	0.645	23589
Animal or vegetable fat~l	.	.	.	.	0.297+	1659
Prepared foodstuff; bev~s	7	7	0.396	0.396	0.345	286598
Mineral products	1	1	-0.847	-0.847	-0.688	24622
Products of the chemica~i	10	11	1.125	0.885	0.453	275259
Plastics and articles t~r	7	7	0.406	0.406	0.589	316553
Raw hides and skins le~u	10	10	1.069	1.069	0.588	57783
Wood and articles of wo~	4	4	0.381	0.381	0.555	85477
Pulp of wood or of othe~s	5	5	0.858	0.858	0.494	178363
Textiles and textiles a~s	3	3	0.534	0.534	0.459	858101
Footwear headgear umb~s	3	3	0.839	0.839	1.240	88393
Articles of stone plas~e	.	.	.	.	0.244+	55487
Natural or cultured pea~c	4	4	1.387	1.387	0.751	56133
Base metals and article~e	.	.	.	.	0.316+	1005894
Machinery and mechanica~a	11	11	0.486	0.486	0.294	1461352
Vehicle aircraft vess~a	.	.	.	.	-0.126+	115834
Optical photographic ~g	4	4	0.333	0.333	0.420	759011
Arms and ammunition; pa~a	12	24	21.228	6.198	3.368	2005
Miscellaneous manufactu~c	2	2	0.928	0.928	0.435	139403

All regressions include augmented 8 digits HS code - country - postal code fixed effects and a 2 digits HS code-country specific trend.
Errors are clustered at the postal code level. The start day represent the first day where the pass-through is different from 0.
The end day represent the first day where the pass-through is different from 0 and not different from the medium-run pass-through.
+ indicates that the medium run pass-through is not significant at the 5% level.

their operating environment. Our findings tend to support state-dependent pricing models by Dotsey et al. (1999) as opposed to time-dependent pricing models by Calvo (1983). Second in forecasting import and export prices, the new pass-through estimates highlight the view that price adjustment is heavily dependent on the nature of the exchange rate shock. Past literature has often focused on price adjustment in response to frequent and small exchange rate shocks, showing that the pass-through tends to be slow. Instead, we document the opposite image: a fast pass-through is uncovered for large shocks.

References

Alessandria, G., S. Pratap, and V. Yue (2015). Export growth and aggregate dynamics in large devaluations. *Mimeo*.

Alvarez, F., F. Lippi, and J. Passadore (2016). Are state and time dependent models really different? *mimeo*.

Amiti, M., O. Itskhoki, and J. Konings (2014). Importers, exporters, and exchange rate disconnect. *American Economic Review 104*(7), 1942–78.

Amiti, M. and D. Weinstein (2011). Exports and financial shocks. *Quarterly Journal of Economics 126*(4), 1841–1877.

Auer, R., T. Chaney, and P. Sauré (2014). Quality pricing-to-market. *CEPR Discussion Paper No. DP10053*.

Auer, R. and R. Schoenle (2016). Market structure and exchange rate pass-through. *Journal of International Economics 98*(C), 60–77.

Bacchetta, P. and E. Van Wincoop (2005). A theory of the currency denomination of international trade. *Journal of International Economics 67*(2), 295–319.

Bakhshi, H., H. Khan, and B. Rudolf (2007). The phillips curve under state-dependent pricing. *Journal of Monetary Economics 54*(8), 2321–2345.

Berman, N., P. Martin, and T. Mayer (2012). How do different exporters react to exchange rate changes? *Quarterly Journal of Economics 127*(1), 437–492.

Bils, M. and P. Klenow (2004). Some evidence on the importance of sticky prices. *Journal of Political Economy 112*(5), 947–985.

BIS (2014). Trade finance: developments and issues. *CGFS Papers 50*.

Burstein, A., M. Eichenbaum, and S. Rebelo (2005). Large devaluations and the real exchange rate. *Journal of Political Economy 113*(4), 742–784.

Burstein, A. and N. Jaimovich (2012). Understanding movements in aggregate and product-level real exchange rates. *Mimeo*.

Calvo, G. (1983). Staggered prices in a utility-maximizing framework. *Journal of Monetary Economics 12*(3), 383–398.

Campa, J. M. and L. Goldberg (2005). Exchange rate pass-through into import prices. *Review of Economics and Statistics 87*(4), 679–690.

Chen, N. and L. Juvenal (2013). Quality, trade, and exchange rate pass-through. CEPR Discussion Papers 9744.

Chen, Y.-C. and K. Rogoff (2003). Commodity currencies. *Journal of international Economics 60*(1), 133–160.

Correia, S. (2015). REGHDFE: Stata module to perform linear or instrumental-variable regression absorbing any number of high-dimensional fixed effects. Statistical Software Components, Boston College Department of Economics.

Corsetti, G., L. Dedola, and S. Leduc (2008). High exchange-rate volatility and low pass-through. *Journal of Monetary Economics 55*(6), 1113–1128.

Cravino, J. and A. Levchenko (2015). The distributional consequences of large devaluations. *Mimeo*.

Devereux, M., B. Tomlin, and W. Dong (2015). Exchange rate pass-through, currency of invoicing and market share. Working Paper 21413, National Bureau of Economic Research.

Dixit, A. (1989). Hysteresis, import penetration, and exchange rate pass-through. *Quarterly Journal of Economics*, 205–228.

Dotsey, M., R. King, and A. Wolman (1999). State-dependent pricing and the general equilibrium dynamics of money and output. *Quarterly Journal of Economics*, 655–690.

Efing, M., R. Fahlenbrach, C. Herpfer, and P. Krueger (2015). How do investors and firms react to an unexpected currency appreciation shock? *Swiss Finance Institute Research Paper* (15-65).

Egger, P. and A. Lassmann (2015). The causal impact of common native language on international trade: evidence from a spatial regression discontinuity design. *The Economic Journal 125*(584), 699–745.

Enders, Z., G. Müller, and A. Scholl (2011). How do fiscal and technology shocks affect real exchange rates?: New evidence for the United States. *Journal of International Economics 83*(1), 53–69.

Engel, C. (2006). Equivalence results for optimal pass-through, optimal indexing to exchange rates, and optimal choice of currency for export pricing. *Journal of the European Economic Association 4*(6), 1249–1260.

Engel, C. and K. West (2005). Exchange rates and fundamentals. *Journal of Political Economy 113*(3), 485–517.

Feenstra, R. (1989). Symmetric pass-through of tariffs and exchange rates under imperfect competition: An empirical test. *Journal of International Economics 27*(1), 25–45.

Feltrin, C. and B. Guimaraes (2015). Time-dependent or state-dependent pricing? Evidence from a large devaluation episode. *Mimeo*.

Flach, L. (2014). Quality upgrading and price heterogeneity: evidence from Brazilian exporters. *Mimeo*.

Gagnon, E. (2009). Price setting during low and high inflation: evidence from Mexico. *Quarterly Journal of Economics 124*(3), 1221–1263.

Gagnon, E., B. R. Mandel, and R. J. Vigfusson (2014). Missing import price changes and low exchange rate pass-through. *American Economic Journal: Macroeconomics 6*(2), 156–206.

Goldberg, L. and C. Tille (2008). Vehicle currency use in international trade. *Journal of International Economics 76*(2), 177–192.

Golosov, M. and R. Lucas (2007). Menu costs and phillips curves. *Journal of Political Economy 115*(2), 171–199.

Gopinath, G. (2015). The international price system. Technical report, National Bureau of Economic Research.

Gopinath, G., O. Itskhoki, and R. Rigobon (2010). Currency choice and exchange rate pass-through. *American Economic Review 100*(1), 304–336.

Gopinath, G. and R. Rigobon (2008). Sticky borders. *Quarterly Journal of Economics*, 531–575.

Gorodnichenko, Y. and O. Talavera (2014). Price setting in online markets: Basic facts, international comparisons, and cross-border integration. *NBER Working Paper* (20406).

Grinberg, F. (2015). Large currency depreciations and menu costs. *Mimeo*.

Kaufmann, D. (2009). Price-setting behaviour in Switzerland: evidence from CPI micro data. *Swiss Journal of Economics and Statistics 145*(III), 293–349.

Kenen, P. (2011). Currency internationalisation: an overview. In B. for International Settlements (Ed.), *Currency internationalisation: lessons from the global financial crisis and prospects for the future in Asia and the Pacific*, Volume 61 of *BIS Papers chapters*, pp. 9–18. Bank for International Settlements.

Kropf, A. and P. Sauré (2014). Fixed costs per shipment. *Journal of International Economics 92*(1), 166–184.

Lein, S. (2010). When do firms adjust prices? Evidence from micro panel data. *Journal of Monetary Economics 57*(6), 696–715.

Mankiw, G. and R. Reis (2002). Sticky information versus sticky prices: A proposal to replace the new keynesian phillips curve. *The Quarterly Journal of Economics 117*(4), 1295–1328.

Meese, R. and K. Rogoff (1988). Was it real? the exchange rate-interest differential relation over the modern floating-rate period. *Journal of Finance*, 933–948.

Menon, J. (1995). Exchange rate pass-through. *Journal of Economic Surveys 9*(2), 197–231.

Mirkov, N., I. Pozdeev, and P. Söderlind (2015, November). Did markets anticipate the removal of the swiss franc cap? *Mimeo*.

Nakamura, E. and J. Steinsson (2008). Five facts about prices: a reevaluation of menu cost models. *Quarterly Journal of Economics 123*(4), 1415–1464.

Neiman, B. (2010). Stickiness, synchronization, and pass-through in intrafirm trade prices. *Journal of Monetary Economics 57*(3), 295–308.

Rauch, J. E. (1999). Networks versus markets in international trade. *Journal of international Economics 48*(1), 7–35.

SNB (2015). Business cycle trends. *Swiss National Bank quarterly bulletin* (1), 30–33.

Vavra, J. S. (2013). Inflation dynamics and time-varying volatility: New evidence and an ss interpretation. Technical report, National Bureau of Economic Research.

Verhoogen, E. (2008). Trade, quality upgrading, and wage inequality in the Mexican manufacturing sector. *Quarterly Journal of Economics*, 489–530.

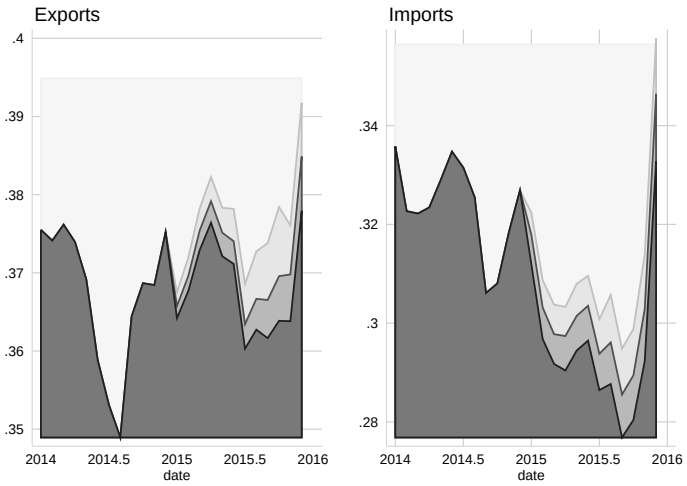
A Appendix 1: Currency switching and the exchange rate shock

This Appendix presents information on whether the pass-through estimates are biased because of currency invoice switching at the time of the exchange rate shock. It is argued in Gopinath et al. (2010) that in the face of small frictions, currency invoice switching should not occur. In the figure below, we show that the Gopinath et al. (2010) claim holds in the face of large shocks for Swiss exports and imports. The figure shows four pictures. Two sets of graphs for exports and imports are presented for the number of transactions and their value. Each of these graphs are shaded as follows: the dark area is the share of euro-invoicing, light is the share of Swiss franc invoicing, light grey is the share of switching from Swiss franc to euro-invoicing after January 15, 2015, and grey is the share of switching from euro to Swiss franc invoicing after January 15, 2015. A switch in currency invoicing is for firm proxied by the triplet: postal code, HS product, and destination/source.

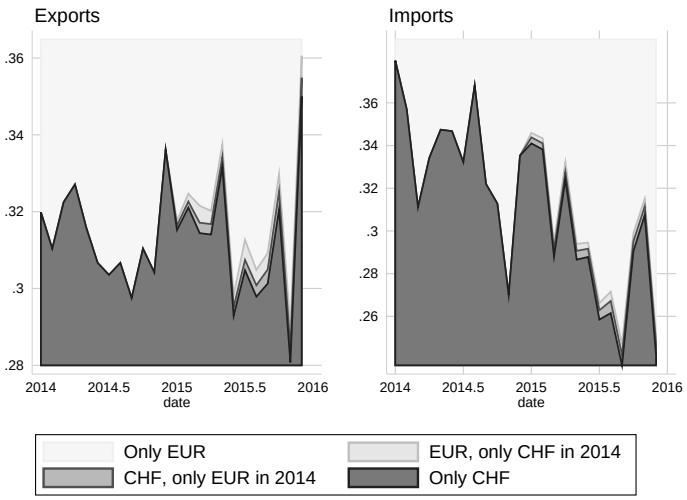
The results show that the level of switching after January 15, 2015 is particularly low. It is less than 0.01% for each of the four categories. Further, the small degree of switching in the invoice currencies occurs in both directions, suggesting that the effect is neutral at best. From this we conclude that our daily pass-through estimates are not subject to switching effects at the time of the exchange rate shock.

Figure 8: **Currency switching in 2015 - Swiss trade with the euro area**

(a) Based on Transactions



(b) Based on Values



Notes: The dark area is the share of euro invoicing, light is the share of Swiss franc invoicing, light gray area is the share of switching from Swiss franc to euro invoicing after January 15, 2015, and gray is the share of switching from euro to Swiss franc invoicing after January 15, 2015.

B Appendix 2: Graphs to the robustness checks

4.2 Graphs for proxying firm size

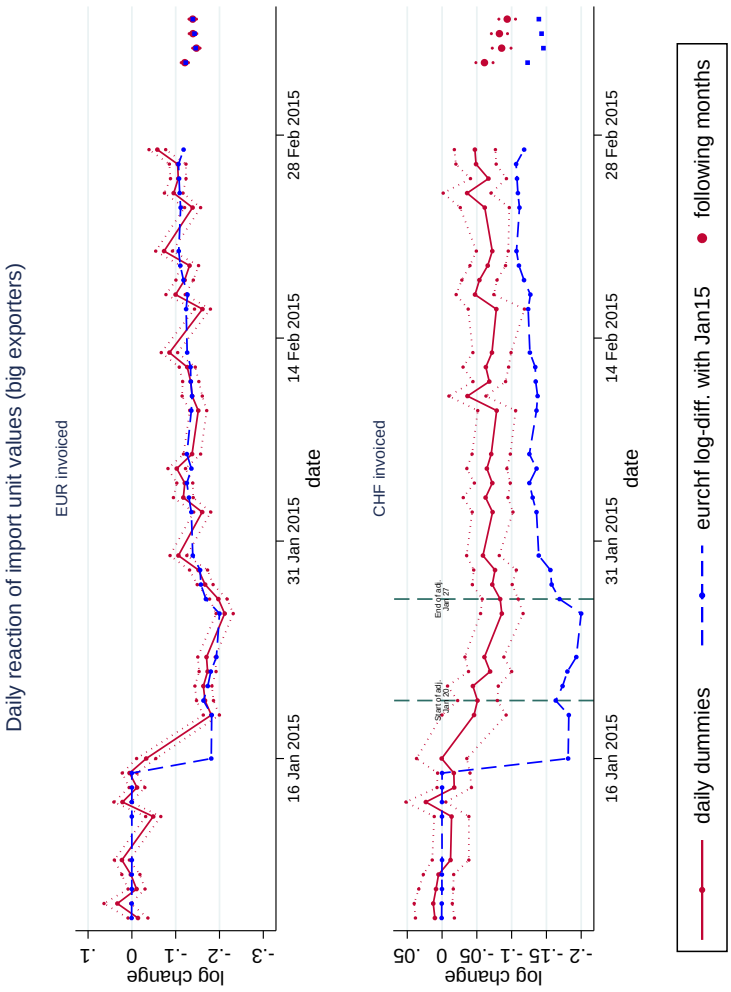


Figure 9: Daily dummies for import unit values from big HS-country export combinations (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a 2-digit HS -country specific trend. Error are clustered at the postal code level.

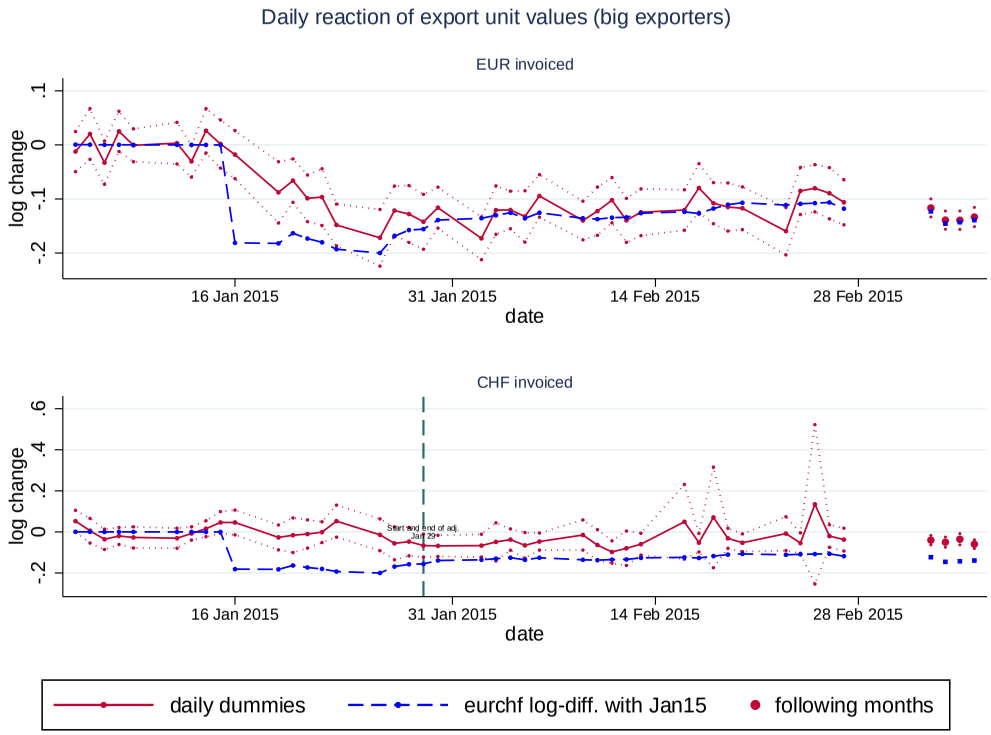


Figure 10: Daily dummies for export unit values of big HS-postal code combinations (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a 2-digit HS -country specific trend. Error are clustered at the postal code level.

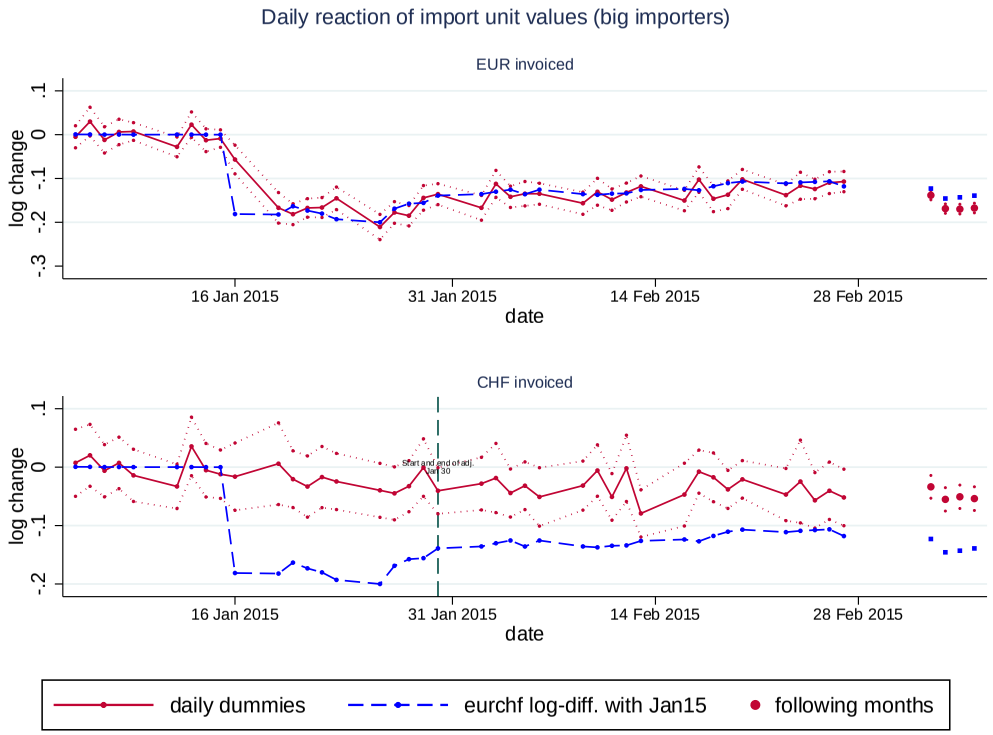


Figure 11: Daily dummies for import unit values of big HS-postal code importer combinations (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a 2-digit HS -country specific trend. Error are clustered at the postal code level.

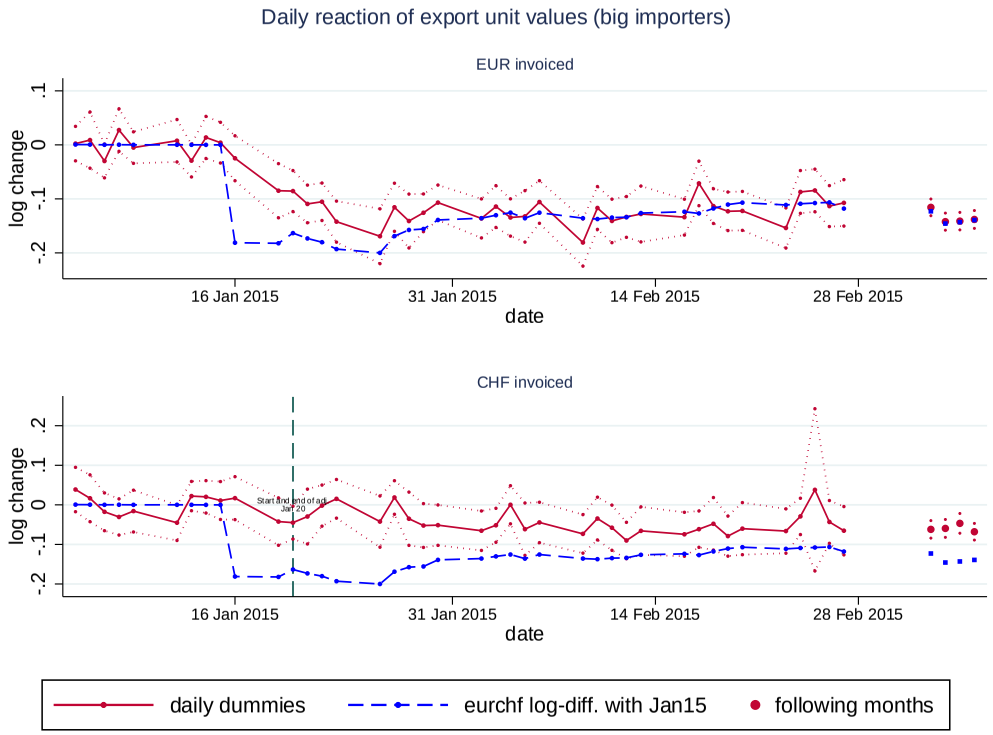


Figure 12: Daily dummies for export unit values to big HS-country importing combinations (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a 2-digit HS -country specific trend. Error are clustered at the postal code level.

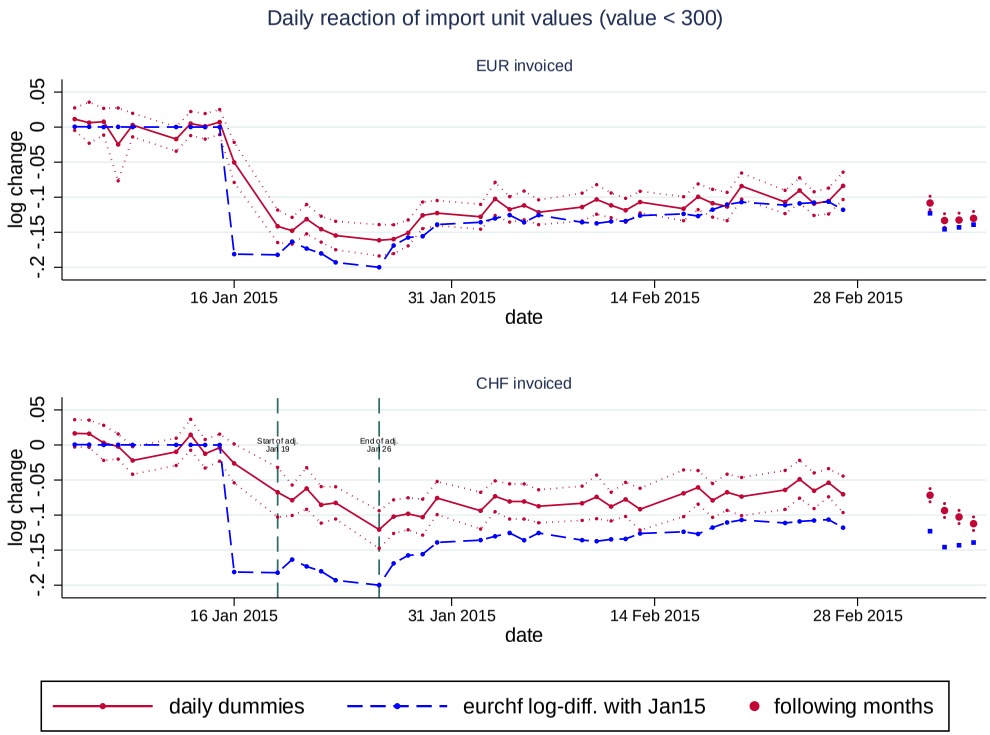


Figure 13: Daily dummies for import unit values for shipments worth less than CHF 300 (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a 2-digit HS -country specific trend. Errors are clustered at the postal code level.

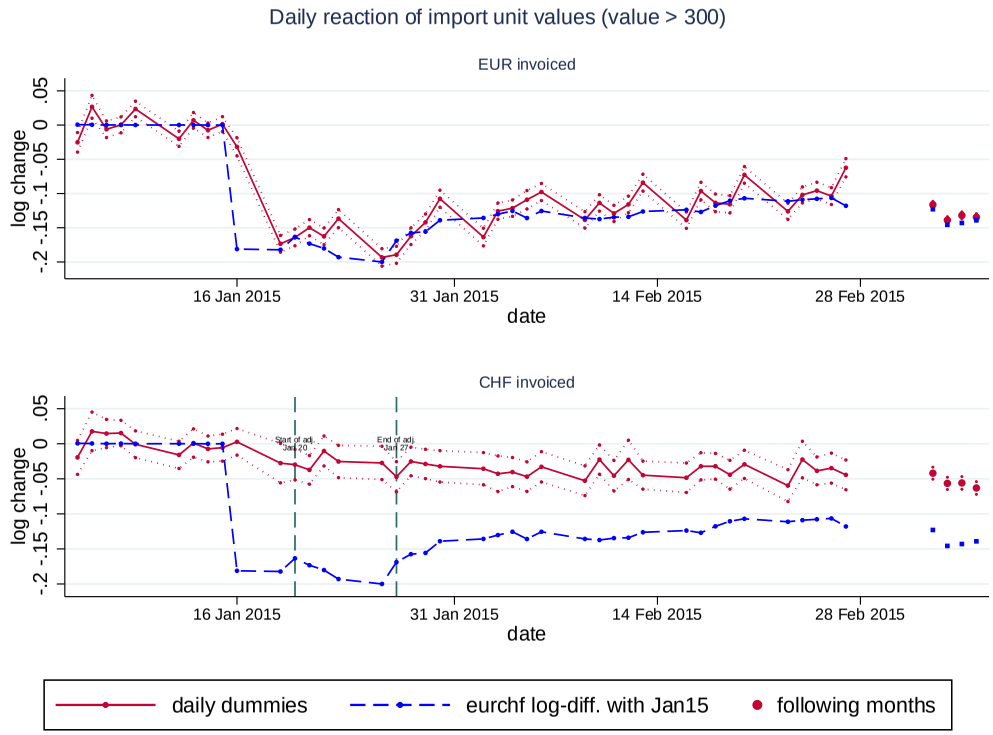


Figure 14: Daily dummies for import unit values for shipments worth more than CHF 300 (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a 2-digit HS-country specific trend. Errors are clustered at the postal code level.

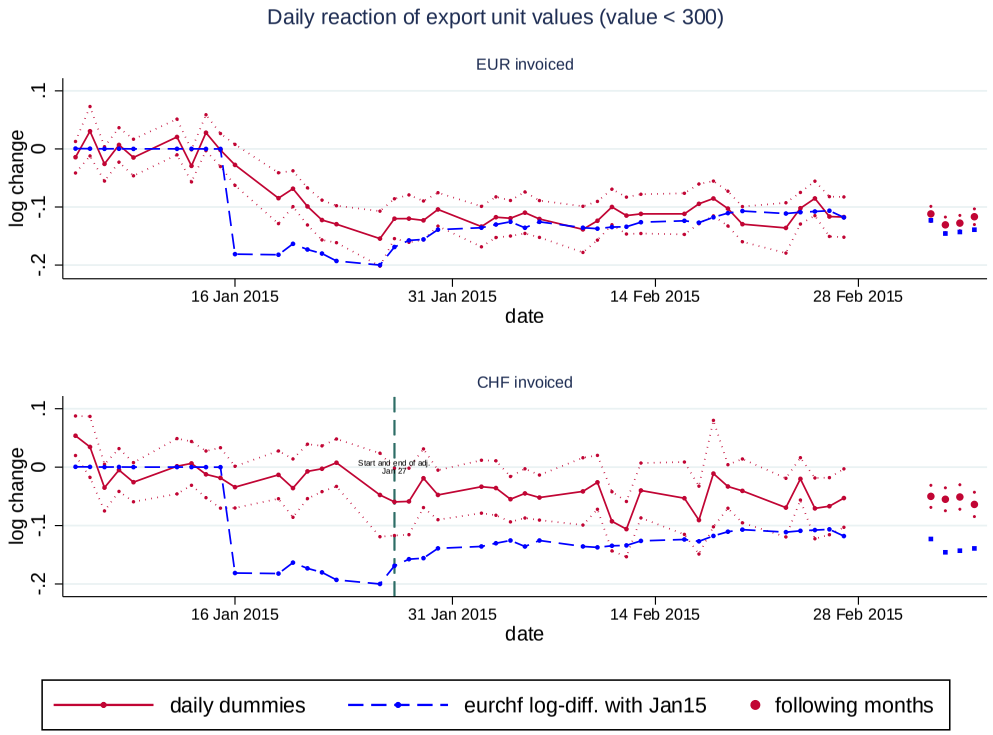


Figure 15: Daily dummies for export unit values for shipments worth less than CHF 300 (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a 2-digit HS -country specific trend. Errors are clustered at the postal code level.

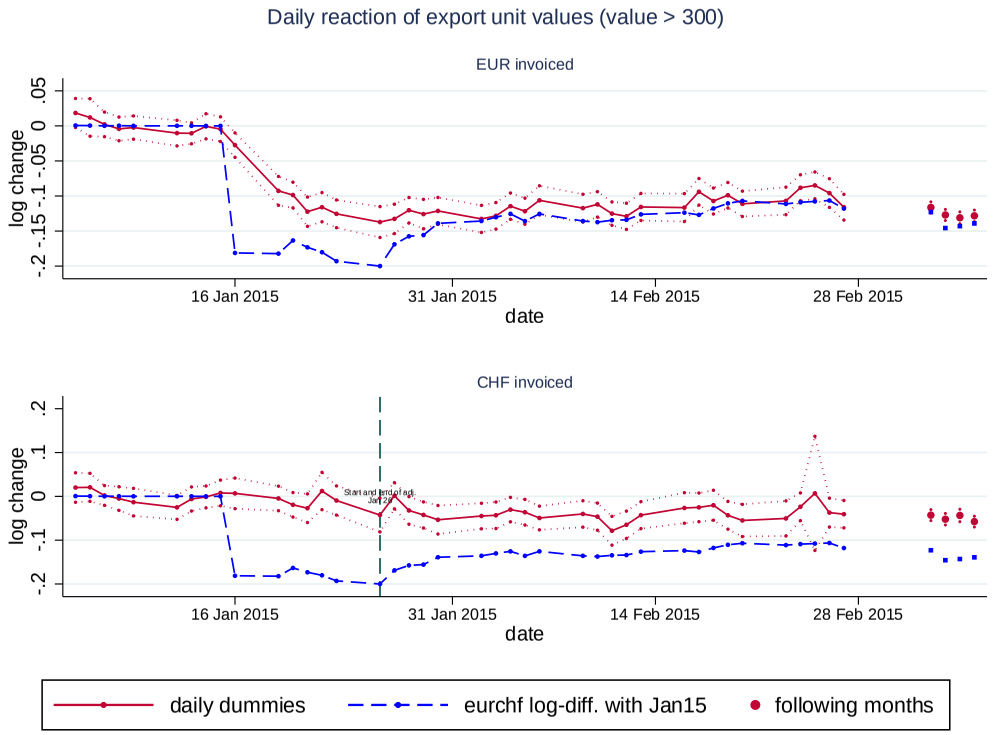


Figure 16: Daily dummies for export unit values for shipments worth more than CHF 300 (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a 2-digit HS -country specific trend. Errors are clustered at the postal code level.

4.3 Graphs for intermediate, investment and consumption goods

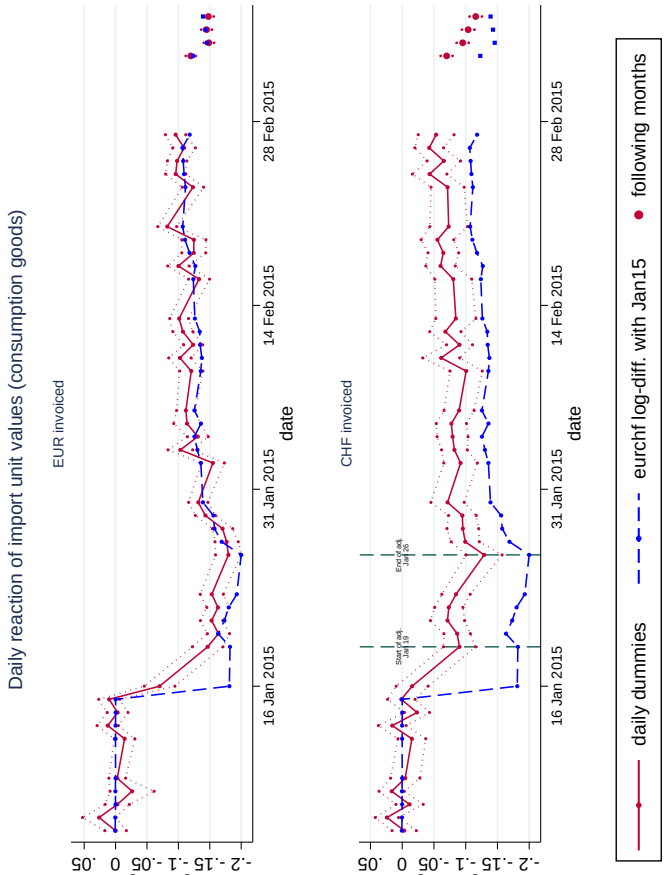


Figure 17: Daily dummies for import unit values for consumption goods (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a 2-digit HS -country specific trend. Errors are clustered at the postal code level.

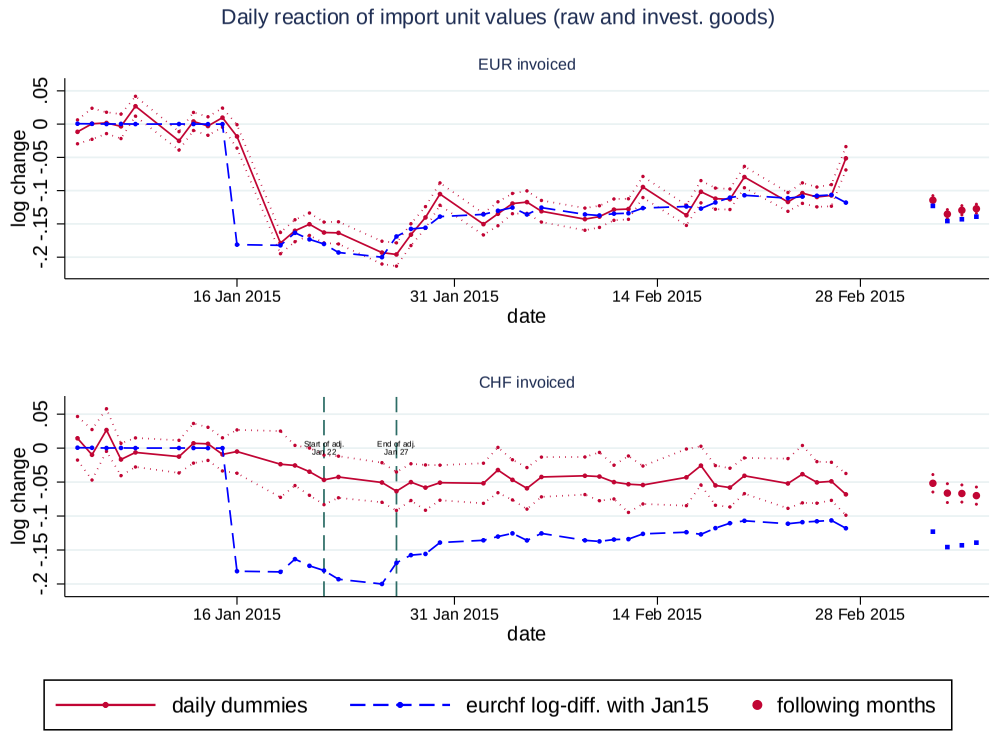


Figure 18: Daily dummies for import unit values for investment goods and raw materials (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a 2-digit HS-country specific trend. Errors are clustered at the postal code level.

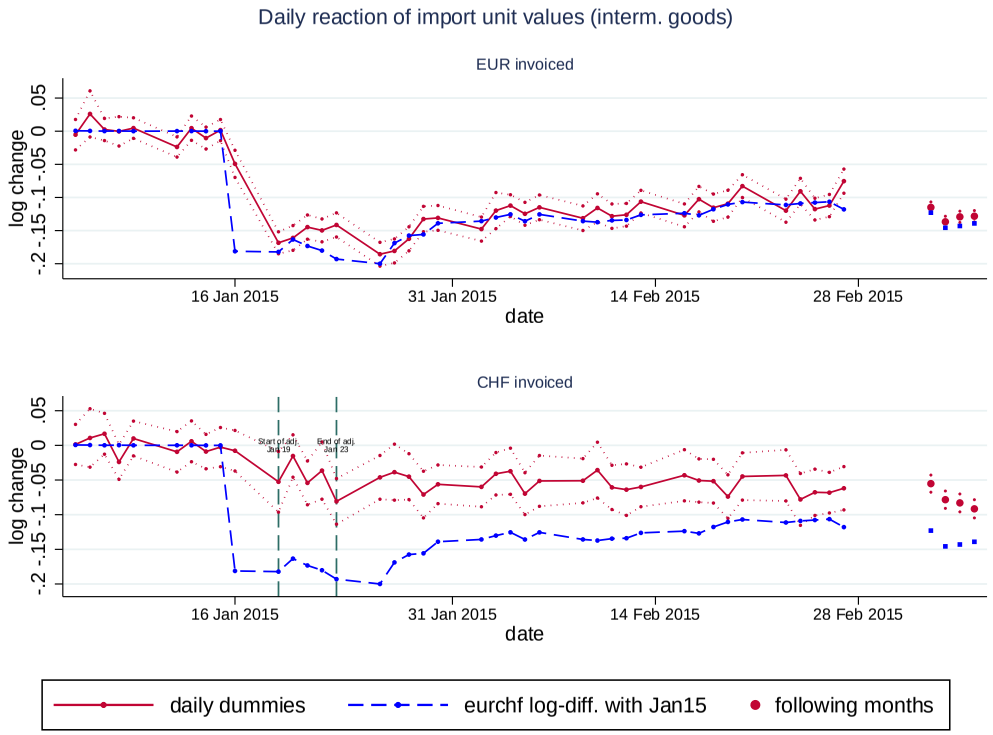


Figure 19: Daily dummies for import unit values for intermediate goods (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a 2-digit HS-country specific trend. Errors are clustered at the postal code level.

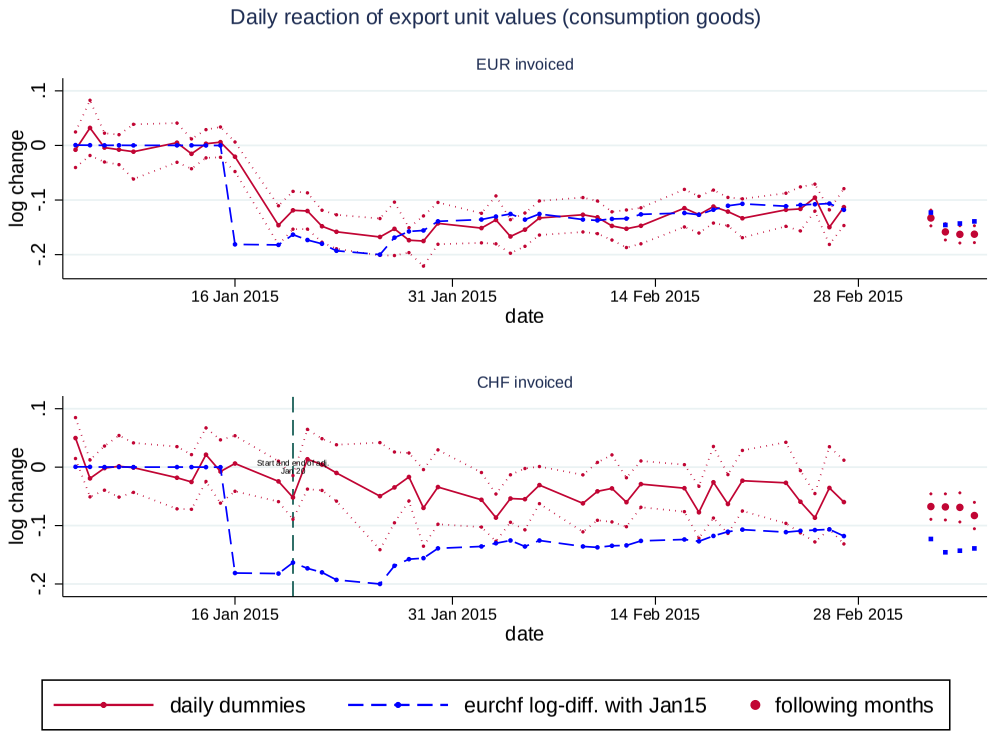


Figure 20: Daily dummies for export unit values for consumption goods (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a 2-digit HS-country specific trend. Errors are clustered at the postal code level.

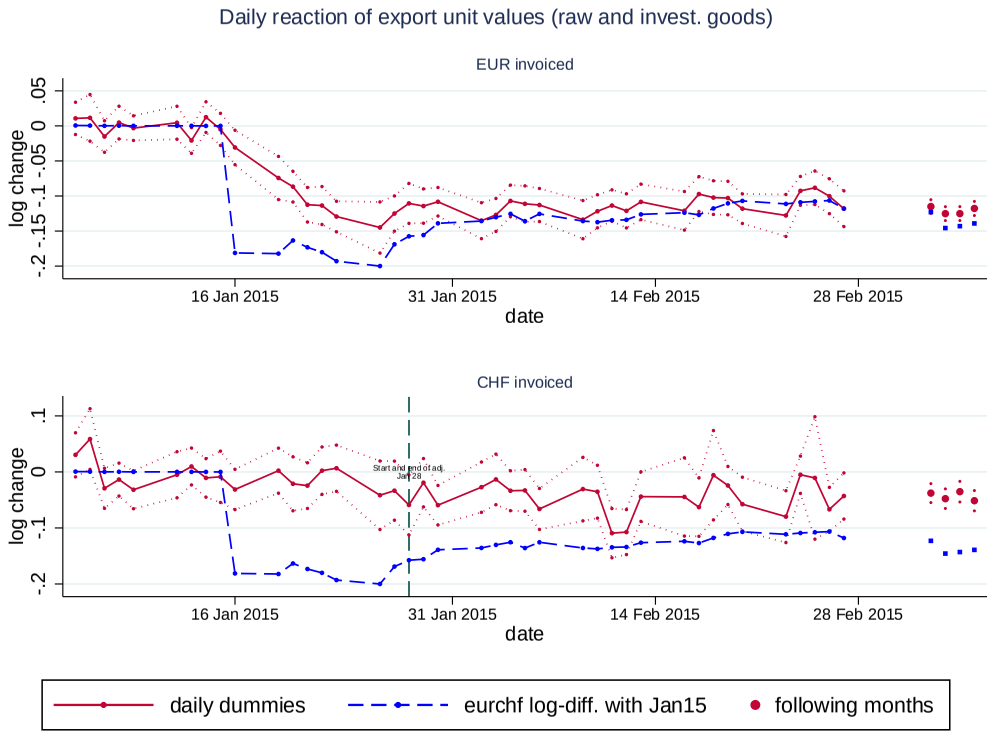


Figure 21: Daily dummies for export unit values for investment goods and raw materials (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a 2-digit HS country specific trend. Errors are clustered at the postal code level.

Figure 22: Daily dummies for export unit values for intermediate goods (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a 2-digit HS country specific trend. Errors are clustered at the postal code level.

4.4 Graphs by Rauch classification

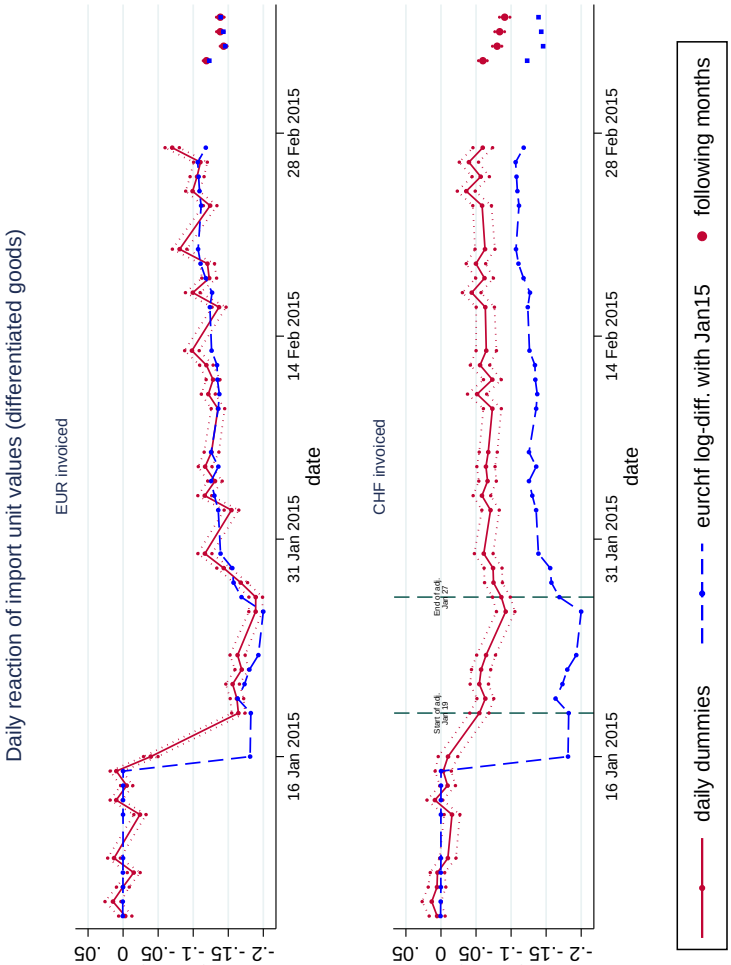


Figure 23: Daily dummies for import unit values of differentiated goods (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a 2-digit HS -country specific trend. Error are clustered at the postal code level.

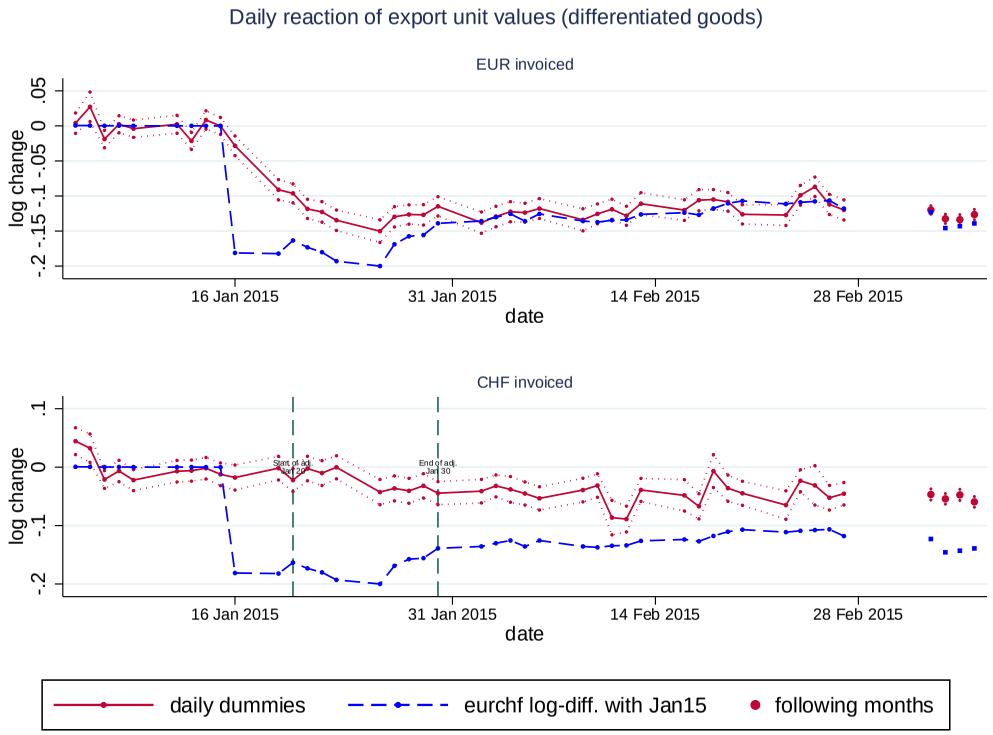


Figure 24: Daily dummies for export unit values of differentiated goods (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a 2-digit HS -country specific trend. Error are clustered at the postal code level.

4.5 Graphs for single item declarations

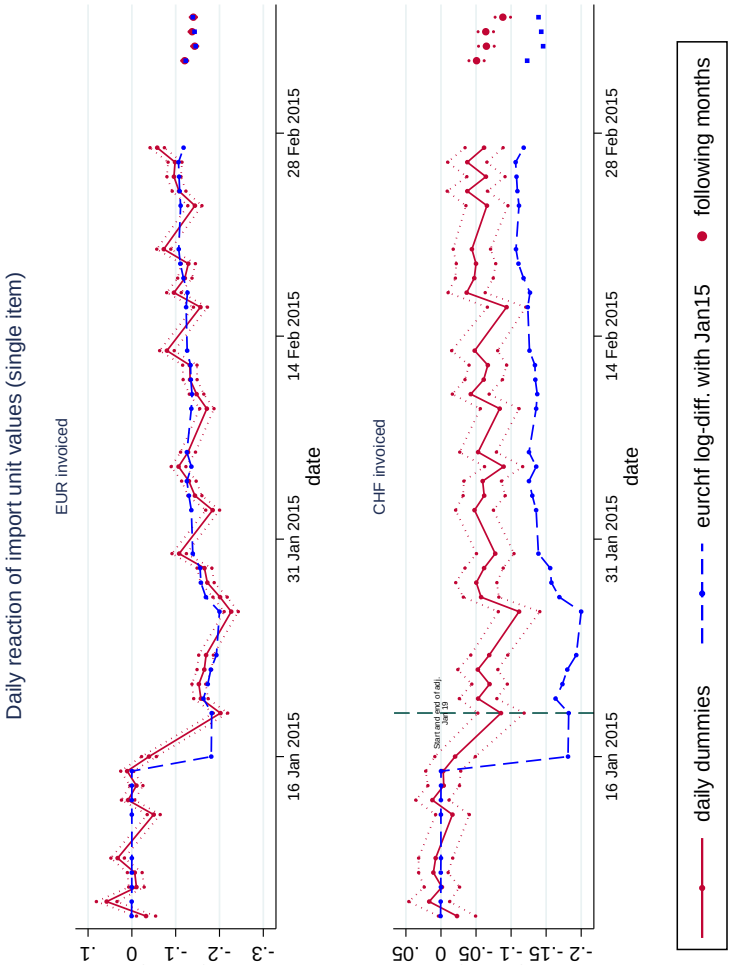


Figure 25: Daily dummies for import unit values when the transaction is unique in the custom declaration (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a 2-digit HS -country specific trend. Error are clustered at the postal code level.

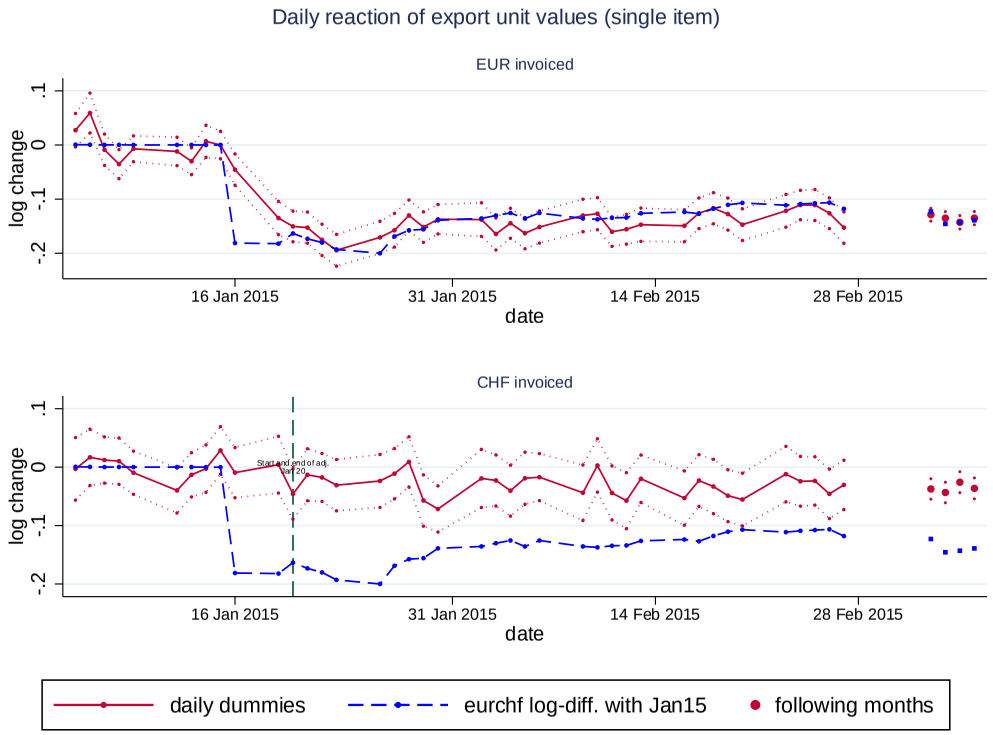


Figure 26: Daily dummies for export unit values when the transaction is unique in the custom declaration (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a 2-digit HS -country specific trend. Error are clustered at the postal code level.

4.6 Graphs for category-level regressions

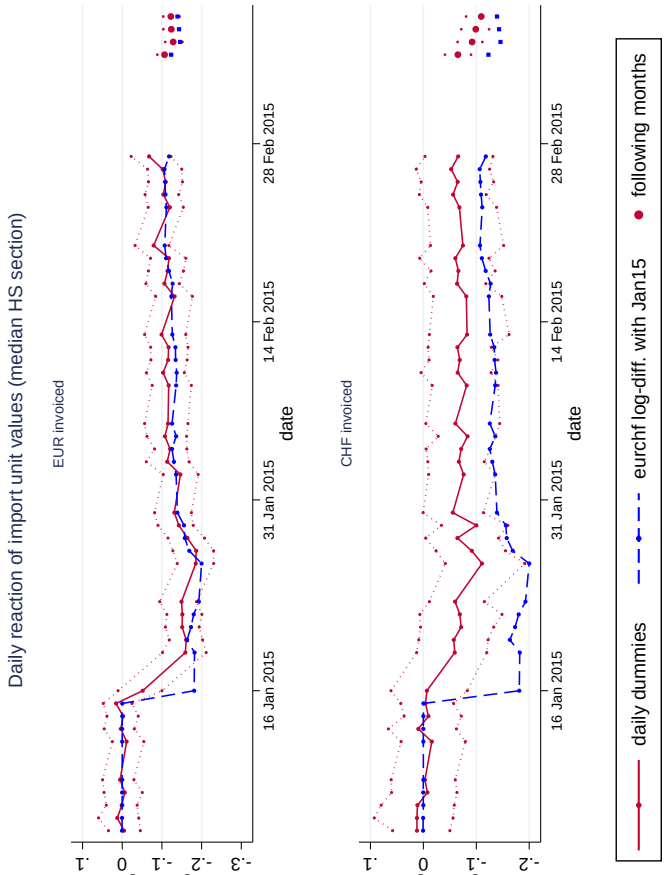


Figure 27: Median of each HS section specific daily coefficients on import unit values (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a country specific trend. Errors are clustered at the postal code level.

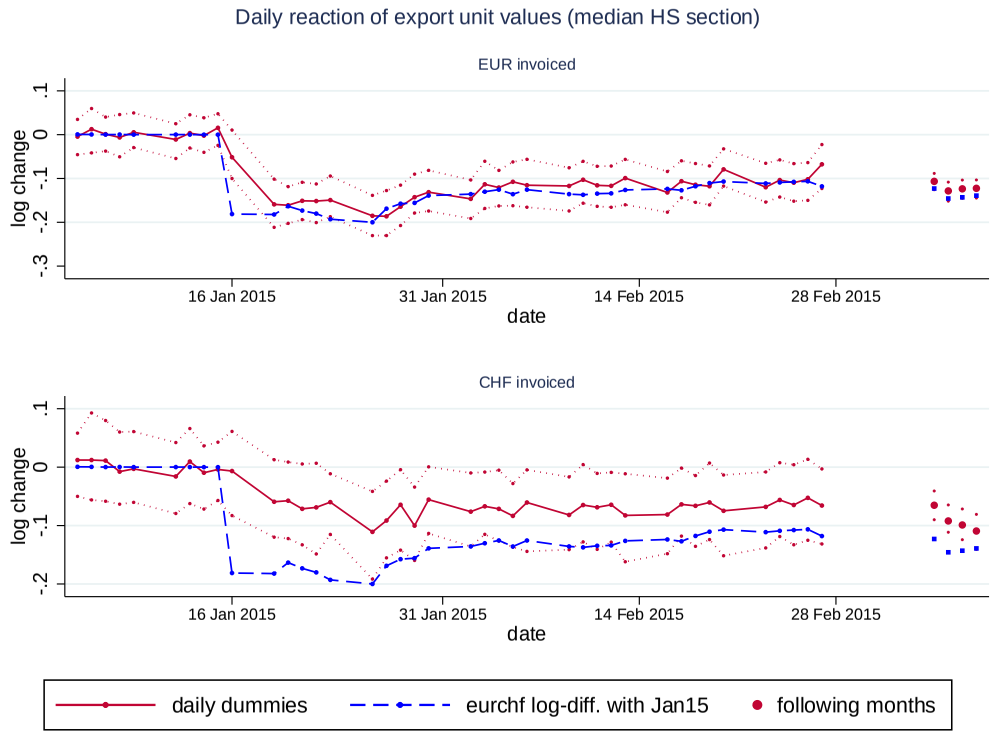


Figure 28: Median of each HS section specific daily coefficients on export unit values (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a country specific trend. Errors are clustered at the postal code level.

C Appendix 3: Standard estimation procedure

Traditional estimates of pass-through into export prices typically take the form

$$\Delta p_{ij,t} = \sum_{l=0}^{L} \beta_l \Delta e_{j,t} + Z_{ij,t}\gamma + u_{ij,t} \tag{3}$$

where $\Delta p_{ij,t}$ denotes the change in the price of good i exported from a given country C to country j, at time t, $\Delta e_{j,t}$ denotes the change in the exchange rate of country C's and country j's currencies, $Z_{ij,t}$ is a set of potentially country- and good-specific control variables and $u_{ij,t}$ is an error term.

Estimations of this specification crucially rely on the underlying assumption that the error term is uncorrelated with the independent variables, that is, $E[\Delta e_{j,t-l} u_{ij,t}] = 0$ holds for all lags included. If this condition is violated, the estimates suffer from endogeneity bias.

In the following paragraphs, we argue that the crucial assumption may be violated through a number effects and mechanisms described by the literature.

Endogeneity would occur if the theoretical price parity condition holds, as the exchange rate and prices should be jointly determined. Although this violation is usually rejected because exchange rate and prices are not found to be cointegrated (see e.g. Campa and Goldberg (2005)), other sources of endogeneity exist and imperfect measurement or omitted variables are likely to affect the estimation. Corsetti et al. (2008), for example, stress the need to correctly control for marginal cost and demand.

In an early paper, Meese and Rogoff (1988) conjecture that real shocks (such as productivity shocks) drive real exchange rate changes. Relatedly, Enders et al. (2011) present evidence that productivity shocks induce appreciations of the real exchange rate. Thus, real shocks may actually drive innovations in the exchange rate and, simultaneously, innovations in producer's cost. If the marginal cost cannot be adequately controlled for, omitting this variable results in biased estimates because $E[\Delta e_{j,t} u_{ij,t}] \neq 0$ if prices adapt instantaneously and $E[\Delta e_{j,t} u_{ij,t+l}] \neq 0$ $(l > 0)$ if they adjust sluggishly.

Engel and West (2005) take a different approach by stressing the asset-price nature of exchange rates. The authors suggest that exchange rates depend on expectations of future fundamentals, arguing, in particular, that innovations in the exchange rates should be correlated with news about future fundamentals. Empirically, they find evidence that exchange rates

Granger-cause fundamentals. In such a setting, an anticipated technological shock impacts the exchange rate at time t, and producer's cost at time $t+l$. Here again, if the marginal cost cannot be correctly controlled for, $u_{ij,t}$ and $\Delta e_{j,t}$ may both react to the same shock, implying that $E[e_{j,t-\hat{l}}u_{ij,t}] = \eta_{\hat{l}} \neq 0$ for a lag $\hat{l} > 0$.[53]

To frame these arguments formally, consider the following OLS estimator of $(\beta', \gamma')'$ in (3):

$$\begin{pmatrix} \hat{\beta} \\ \hat{\gamma} \end{pmatrix} = \begin{pmatrix} \beta \\ \gamma \end{pmatrix} + \begin{pmatrix} e'e & e'Z \\ Z'e & Z'Z \end{pmatrix}^{-1} \begin{pmatrix} e'u \\ Z'u \end{pmatrix} \tag{4}$$

where $e = (\ \Delta e_0\ \Delta e_1\ ...\ \Delta e_L\ )$ is the matrix of exchange rate lags, Z the matrix of control variables and u the error vector. Inverting the partitioned matrix, the bias on $\hat{\beta}$ is given by:

$$\hat{\beta} - \beta = \begin{pmatrix} A & -A(e'Z)(Z'^{-1} \\ & \end{pmatrix} \begin{pmatrix} e'u \\ Z'u \end{pmatrix} \tag{5}$$

with $A = (e'e - e'Z(Z'Z)^{-1}Z'e)^{-1} = (e'M_z e)^{-1}$. If all variables in Z are exogenous, we get that $plim\frac{Z'u}{T} = 0$, so that the direction of the asymptotic bias only depends on the behavior of A and $e'u$.

In the case that the lags of exchange rate changes are uncorrelated (for example in the case of a random walk in the exchange rate), $plim A$ is a diagonal matrix whose elements are equal to $plim(e_l' M_z e_l)^{-1}$, which is positive because M_z is positive definite. The asymptotic bias on each $\hat{\beta}_{\hat{l}}$ is then equal to $\hat{A}_{\hat{l}}\eta_{\hat{l}}$, where $\hat{A}_{\hat{l}} = plim(e_{\hat{l}}' M_z e_{\hat{l}})^{-1}$, and is thus of the same sign as $\eta_{\hat{l}}$. If, in addition, the error terms are autocorrelated[54], the bias does not affect $\hat{\beta}_l$ only. For example, if $u_{ij,t} = \rho u_{ij,t-1} + \epsilon_t$, then $E[u_{ij,t}\Delta e_{j,t-\hat{l}-l}] = \rho^l \eta_{\hat{l}} \neq 0$ follows for $l > 0$ so that all estimates on lags "further away" than $\hat{l}$ are inconsistent. The direction of the bias then depends on $\eta_{\hat{l}}$ and on ρ.

For a concrete example, consider a positive anticipated shock to the technology of the exporting country in a world like in Engel and West (2005).

[53] If the marginal cost is measured with an error (e.g. proxied using expenditure shares and price changes of input prices), the exchange rate will still be correlated with $u_{ij,t}$ if it is also correlated with the measurement error. An other example is a shock in preferences in the demand for the exporter's good which would have a similarly uncontrolled effect on both the price and the exchange rate.

[54] Note that using residuals derived from the inconsistent $\hat{\beta}$, one might be unable to detect such autocorrelation because in this case the residuals are not a consistent estimator of the error term.

In this setup, the anticipated technology shock in period t leads to an appreciation of the exchange rate at time $t-l$. Defining the exchange rate as home currency per foreign currency, this means $\Delta e_{j,t-\hat{l}} < 0$. At the same time, this shock is associated with a negative shock on the price at time t ($u_{ij,t} < 0$). In sum, such a positive technological shock (inducing an appreciation of the exporter's currency and a future reduction in costs) generates $\eta_{\hat{l}} > 0$. A positive ρ is consistent with persistency in the shock. Overall, the bias on the lags would thus be positive, resulting in an overestimation of the delayed pass-through.

The shock to the EURCHF exchange rate used in this paper is arguably unrelated to any shock that might produce endogeneity issues. The shock was unrelated to any technological or taste shock, but was purely due to the SNB's decision. Thus, our estimates take place in a setting free of endogeneity concerns.