# The Speed of Exchange Rate Pass-Through*

Barthélémy Bonadio
University of Michigan

Andreas M. Fischer,†
Swiss National Bank
and CEPR

Philip Sauré
Swiss National Bank

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**Abstract**

On January 15, 2015, the Swiss National Bank terminated its minimum exchange rate policy of one euro against 1.2 Swiss francs. This policy shift resulted in a sharp, unanticipated and permanent appreciation of the Swiss franc by more than 11% against the euro. We analyze the exchange rate pass-through into import unit values of this shock at the daily frequency using Swiss transaction-level trade data. Our key findings are twofold. First, for goods invoiced in euro the pass-through is immediate and complete. This finding is consistent with no systematic nominal price adjustment in this subset of goods. Second, for goods invoiced in Swiss francs the pass-through is partial and very 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. We interpret the latter finding as evidence that nominal rigidities unravelled quickly in the face of a large exchange rate shock.

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

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†Email: andreas.fischer@snb.ch.

# 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, but 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, with typical adjustment periods ranging 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. The 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 of about 11% against the euro. We analyze the response of import unit values to this exchange rate shock at the daily frequency for different invoicing currencies. Because the shock is particularly clean and persistent for the bilateral exchange rate between euro and Swiss franc, we restrict our study to import transactions from the euro area, which accounts for two thirds of all Swiss imports.

Our results are twofold. First, for goods invoiced in euro the exchange rate pass-through is immediate and complete: the import unit values move one-to-one with the exchange rate a day after the exchange rate shock as well as six months later. Second, for goods invoiced in Swiss francs the pass-through is partial and extremely fast. Unit values start to adjust on the second working day after the shock and the pass-through after eight working days is, in a statistical sense, indistinguishable from the pass-through after six months. Our finding of the remarkable speed of pass-through is robust to restrictions to sub-categories of goods and a large number of cuts through the data.

Although we analyse unit values, we argue that our findings are informative about underlying price changes. The first of our findings suggests that there is no systematic nominal price adjustment within the set of euro invoiced goods: nominal euro prices remain unchanged so that the Swiss

[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.

franc denominated unit values react mechanically and instantaneously to exchange rate changes. The second of our findings, in contrast, suggests that prices of Swiss francs invoiced goods do adjust and, moreover, the adjustment is extremely fast. Together, both findings confirm earlier studies, which show that the invoicing currency is the central determinant of the exchange rate pass-through (see Gopinath et al. (2010) and Gopinath (2015)). This is remarkable in view of the fact that we analyze an exceptionally large shock, which could be expected to minimize the differences in the effect of the invoicing currencies. Most importantly, however, we interpret our two empirical findings as evidence that those firms that decided to adjust their border prices in reaction to the exchange rate shock did so very quickly – i.e., within the short period of eight working days after the shock. Put differently, if a firm's optimal response to the exchange rate shock was to change its border price, this price change was implemented extremely fast.

Our preferred interpretation of the remarkably fast pass-through for Swiss franc invoiced goods is that the suddenness and size the January 15, 2015 exchange rate shock quickly undid frictions defined by staggered contracts or lengthy deliveries. Of course, this does not imply that nominal frictions are nonexistent. Instead, our findings indicate that firms are able to overcome frictions 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 can be expected to be written with a horizon of quarters, with nominal frictions of corresponding horizons.[3]

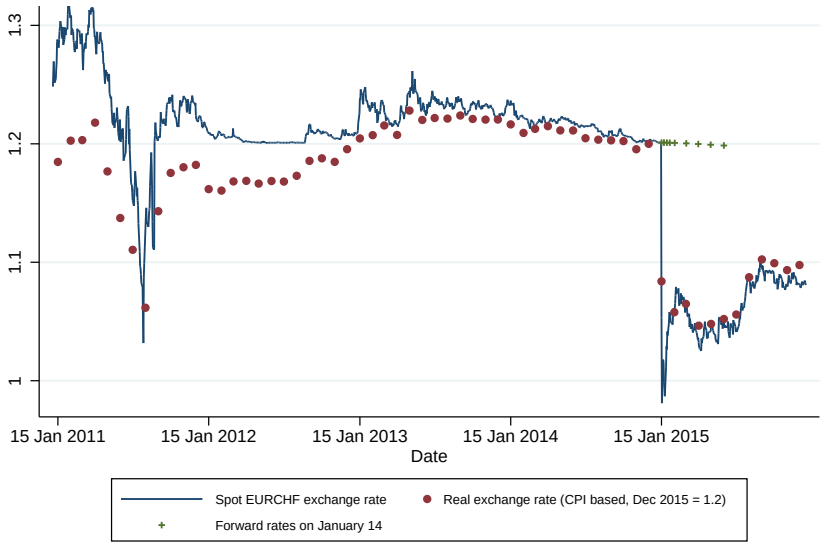
In view of the fact that price adjustments are rather infrequent in normal times, we read our findings as supportive of state-dependent pricing frameworks à la Dotsey et al. (1999) and Golosov and Lucas (2007). Our study may in that respect add valuable information for refined calibrations of state-dependent pricing models. We thus add 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]

[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 the best of our knowledge, this paper is the first to estimate the exchange rate pass-through at the daily frequency. The analysis at the daily frequency only makes 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 the 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 exchange rate shock on January 15, 2015 was not anticipated by financial markets.

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




Sources: SNB, Datastream

The gains from working with an unusually detailed dataset containing the day and invoicing currency of transactions require us to compromise in

to impact inflation persistence and the determinants of Phillips Curves, as analyzed in Bakhshi et al. (2007).

other dimensions. The dataset does 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. Close 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 adapt to a lesser degree due to distribution 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 decomposition is important to disentangle mechanical and nominal adjustment of border prices. In contrast to Burstein et al. (2005), this distinction 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 exchange rate pass-through between 1 (for imports invoiced in euro) and 0.6 (for imports invoiced in Swiss francs) is in line with these previous estimates.

The sharp difference of the exchange rate pass-through across currency groups documented in our analysis is very much in line with the recent literature, which highlights the role of invoicing currencies for the exchange rate pass-through.[6] Specifically, Gopinath et al. (2010) show that the ex-

[5] A fast growing literature has identified a 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 (2016) 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

change rate pass-through into U.S. import prices is complete for non-dollar invoiced imports, but slow and moderate for U.S. dollar invoiced imports. Gopinath (2015) reinforces this point, writing that "international prices, in their currency of invoicing, are not very sensitive to exchange rates" and concludes 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." Our results, in particular those of the euro invoiced sample, show that these findings also tend to hold for the case of a small open economy and under a large exchange rate shock.

Regarding our more specific focus on the speed of price adjustment, the existing empirical evidence suggests that in normal times this speed of adjustment 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) analyze more detailed transaction-level import prices and 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 (2016) 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 imported products at the daily frequency. We attribute the exceptionally fast pass-through to the fact that we analyze a particularly large exchange rate shock. As stressed in a recent study by Alvarez et al. (2016), profit maximizing firms may optimally chose not to adjust prices to small shocks, while the need to adjust prices quickly may rise in the face of large shocks (see also Corsetti et al. (2008)).

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 (2016), 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 distributional effect on income. Alessandria et al. (2015) consider export expansion in emerging markets after a large devaluation. Efing et al. (2015) examine the impact of the Swiss franc exchange rate shock from January

this issue, but similar to Gopinath et al. (2010) and Devereux et al. (2015) take instead this choice as given.

15, 2015 on investor behavior and the real economy on the monthly level. 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 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. Burstein et al. (2005) and Gorodnichenko and Talavera (2016) use 'scanner' (barcode) data and web-based retailers at the weekly frequency.

Finally, we claim that our work makes advances by addressing problems arising due to the endogeneity of exchange rates. It is well known that traditional pass-through estimations suffer identification problems because exchange rates are endogenous.[8] Our shock, however, 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]

[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. In a related paper, Forbes et al. (2015) show that the the nature of shocks matters for the degree of the exchange rate pass-through.

[9]In the appendix, we also discuss the possibility that lagged exchange rates bias tradi-

The remainder of the paper is organized as follows. Section 2 describes the nature of the exchange rate shock and the transaction-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.

# 2 Data description

Our empirical estimates of the speed of exchange rate pass-through relies, first, on a large and exogenous exchange rate shock and, second, on detailed transaction-level trade data at the daily frequency. The discussion of these two features 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 describes the exchange rate shock in detail, arguing that the appreciation was exogenous to firms' border 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 EUR-

tional pass-through estimates.

[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."

CHF 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, increasing differentials in monetary policy actions.[12] We therefore take the EURCHF exchange rate shock as exogeneous to firms' pricing strategies.

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.

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

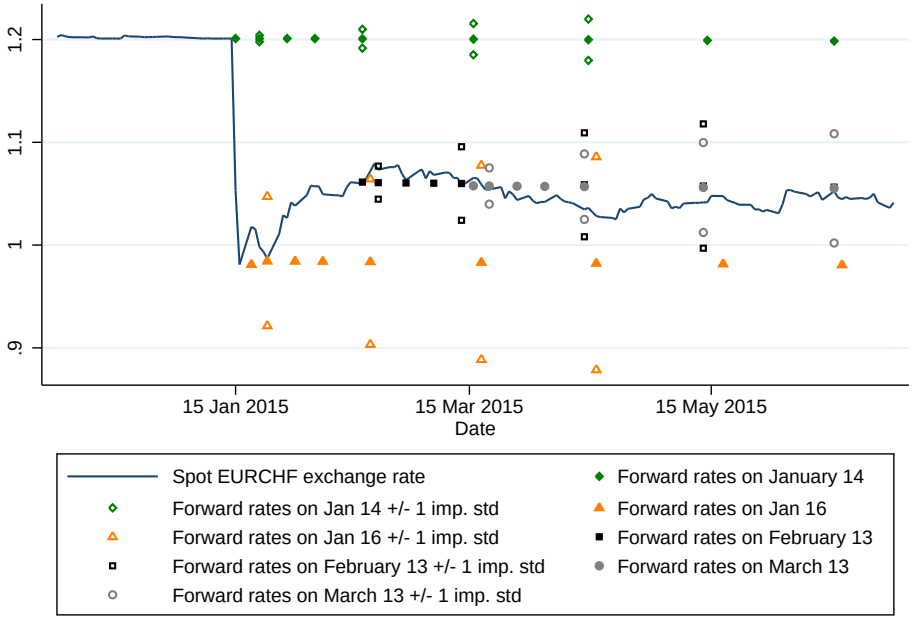
[11] The real exchange rate is constructed using the CPI indices from the euro area and Switzerland and is normalized to 1.2 for December 2014.

[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.

[14] For a study looking at whether 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 preceded the removal of the floor.

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




Sources: SNB, Datastream, own calculations.

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.

These observations underpin the view that the exchange rate drop was not only large but also unanticipated and exogenous to firms' 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,

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

2015. The data include information on the (c.i.f.) value in Swiss francs, 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 transaction-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 included in our dataset.[16] The unit of observation is one transaction.[17] We focus on trade with the euro area, which accounts for 64.6 percent of all imports for the period between January 2014 and June 2015.[18]

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 import transactions is 29.2 million. The share of euro invoicing is around two-thirds. The average daily transactions were more than 50 000 observations for the sample. Differences in the share of euro invoicing between the pre- and post-shock period are small.[19]

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 15 C). We construct unit values by dividing the value of the transaction by the supplementary unit when available and

[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 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] 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] In a robustness check in Section 4.7, we also investigate results regarding imports from the US, which account for 6.5 percent.

[19] 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.

Table 1: Summary statistics

| | Total sample | Pre-shock period | Post-shock period |
|---|---|---|---|
| **Imports** (euro area to Switzerland) | | | |
| *Based on transactions* | | | |
| Average unit value (log) | 3.469 | 3.504 | 3.397 |
| | (2.218) | (2.213) | (2.227) |
| Share invoiced in EUR | 0.676 | 0.668 | 0.692 |
| Share invoiced in CHF | 0.315 | 0.322 | 0.299 |
| Share invoiced in other currencies | 0.009 | 0.009 | 0.009 |
| Share with available supp. units | 0.244 | 0.243 | 0.248 |
| *Based on (log) value* | | | |
| Share invoiced in EUR | 0.659 | 0.654 | 0.672 |
| Share invoiced in CHF | 0.322 | 0.328 | 0.308 |
| Share invoiced in other currencies | 0.018 | 0.017 | 0.021 |
| Share with available supp. units | 0.300 | 0.298 | 0.307 |
| Number of transactions | 29193685 | 19762630 | 9431055 |
| Average number of daily transactions | 53468.29 | 52006.92 | 56813.59 |
| | (33553.95) | (32601.74) | (35513.52) |
| Average EZV EURCHF exchange rate | 1.176 | 1.226 | 1.057 |
| | (0.079) | (0.009) | (0.018) |

Note: standard deviations are shown in parantheses. The total sample spans from January 1, 2014 to June 30, 2015. The pre-shock period goes from Janury 1, 2014 to Janury 15, 2015 while the post-shock period goes from January 16, 2015 to June 30, 2015.

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 goods physically cross the border. 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 the very short run and, in particular, the speed of exchange rate pass-through.

The second key variable records the currency in which transactions are invoiced. For each customs declaration, we know whether the invoicing currency was either of the following five categories: CHF, EUR, USD, other EU

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

currencies and other non-EU 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. The exchange rate is published early in the morning (e.g. 04:30 am for December 14, 2015). On January 15, 2015, in particular, the exchange rate was published before the SNB's 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.[21] Unfortunately, since several transactions can be declared under a single custom declaration but the currency of invoicing is reported at the declaration level, it may happen that transactions invoiced in different currencies are 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 customs declarations with a single cross-border transaction.

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 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 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 imports 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 transac-

[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 motivates our focus on import transactions.

tions (left panel) and based on values (right panel). The figure conveys two messages. First, almost all trade is invoiced either in Swiss francs or euros. Second, the respective shares are stable over time and, in particular, do not appear to have shifted 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 transaction-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 goods 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 investment 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.

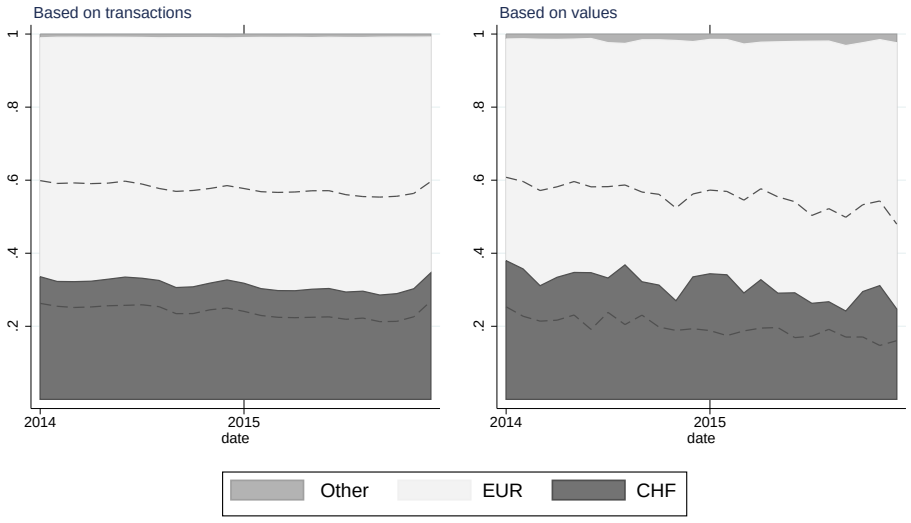
## 3 Estimation strategy and results

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

[22] See, Appendix 2 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 imports from the euro area




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 between the dashed lines represents the share of transactions (value) originating from triplets (postal code - HS - country) that always invoiced in the same currency from January 2014 to December 2015. The areas outside the dashed lines represent the share of transactions (value) originating from a triplets that have invoiced in different currencies.

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 transaction-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 $p_{i,t}$ as the median unit value of the triplet $i$ 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 imported triplet.[24] The bilateral exchange rate, $e_t$ is expressed in CHF per EUR. The EZV exchange rate does not carry any index of the parter country because the focus of our analysis is on Swiss trade with the euro area. $CPI_i$ is the CPI of the exporter country. $X_{i,t}$ 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 (Switzerland). 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. This choice is motivated by the fact that our data have a strongly unbalanced structure, as some triplets don't appear every month in the sample. Excluding these observations would result in a sample bias towards triplets that trade regularly and may be more likely to adjust prices frequently, thus potentially overestimating the pass-through and resulting in results not comparable to the ones presented in the daily section. The 2-digit HS - partner country specific trend ensures that suitable fixed effects remain when differencing equation (1).[25]

The exchange rate movement during the full sample comprises 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.

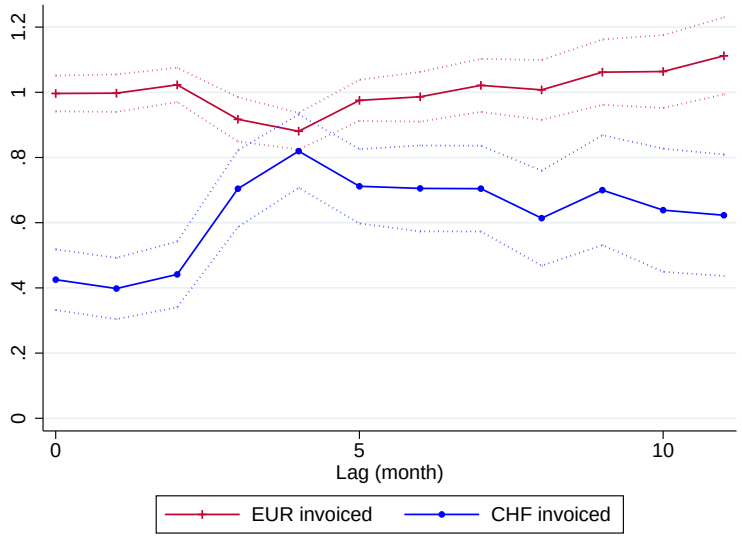
Figure 4 plots the estimated $\beta_m$ for $m$ ranging from 0 (immediate pass-through) to 11. The red line marked with + symbols represents the cumulative pass-through for transactions invoiced in euros and the blue line with bullets those invoiced in Swiss franc.

The pass-through into import unit values of euro invoiced transactions is unsurprisingly equal to 1 for the first lags and stays stable afterward. This

[24] Corresponding estimates for exports corroborate our results regarding the speed of the exchange rate pass-through. These results are reported in an earlier working paper version of this study, which is available upon request.

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

Figure 4: Cumulative pass-through on import 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 sample spans January 2012 to December 2015.

finding mirrors the result uncovered in Gopinath et al. (2010) of full and stable pass-through for import transactions invoiced in the foreign currency.

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 cumulative pass-through of 0.65. This indicates that a large proportion of the pass-through is attained within the month of the shock rather than with a delay.

### 3.2 Daily estimation results

Motivated by the remarkably fast 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 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,

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

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 if 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 time 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 values 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 marginal costs are also unlikely to change in the few weeks after the shock.

[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).

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).[27]

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 cumulative change in unit values (the estimated $\beta_d^D$ 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 cumulative change in unit value and the cumulative change in the exchange rate is not significantly different from the medium-run pass-through ratio, which is defined as the average of the 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.[28] Because of the weak response in unit values 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 presented in graphical form. They include plots of the daily coefficients for euro and Swiss franc invoiced transactions together with their 95% confidence intervals. The medium-run (monthly) estimates are also included in the same plots. Their coefficients are denoted as circles with 95%

[27] 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 January 15 shock. One substantial shock to the EURCHF exchange rate occurs in July 2015, which is excluded from our sample. 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.

[28] Formally, we first define the pre-shock level as the average of the coefficient on dummies $D_{-8}$ to $D_0$ ($PRE = \frac{1}{9}\sum_{i=-8}^{0}\beta_i^D$), 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 cumulative 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.

confidence intervals.[29] Vertical dashed and dotted lines indicate the *start* and *end* day of adjustment when relevant. The cumulative change in the exchange rate relative to the 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.[30]

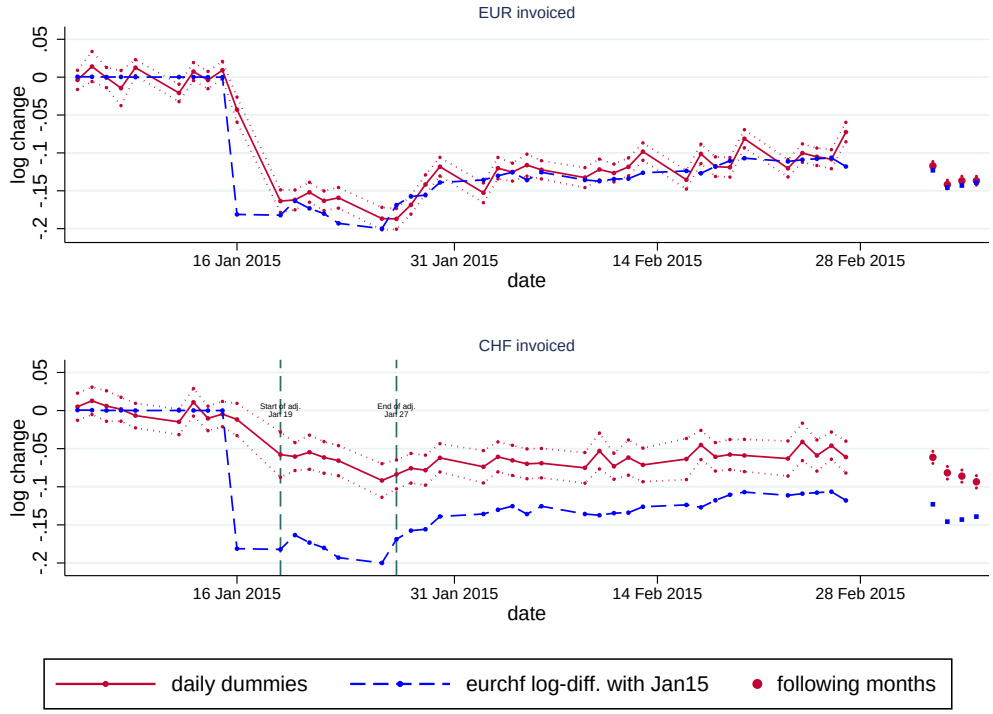
The fast pass-through of imports invoiced in euros is consistent with rigid nominal prices. More striking is the fast responses of unit values of import invoiced in Swiss francs, illustrated in the lower panel of Figure 5. We say the pass-through is *fast* in the sense that the start day and end day 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 0.50 and is not statistically different from the 0.61 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 partial full medium-run pass-through materializes at an exceptionally fast speed.

The sharp difference of the exchange rate pass-through across currency groups 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 show that the exchange rate pass-through into U.S. import prices is complete for non-dollar 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

[29] 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.

[30] 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.

Figure 5: Daily reaction of import unit values




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. The sample spans January 1, 2014 to June 30, 2015.

shock into border prices.

Quite on the contrary, the bottom panel of Figure 5 shows a non-negligible short-run pass-through of the exchange rate shock for transactions invoiced in Swiss francs. We interpret this key finding 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 inducing 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 panel of Figure 5. We corroborate this view by looking at the sign of potential biases that would result from a quality shift. We first observe 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.[32] Finally, we point out that the unit values of imports invoiced in euros (top panel of Figure 5) remained very stable. Again, this observation indicates that strong substitution effects are not affecting this set of transactions.

Exit and entry of firms or products in 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)

[31] We do not take a stance on why nominal prices of Swiss franc-invoiced transactions did adjust, although those of euro-invoiced transactions did not.

[32] Also, a similar 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 should be stronger for exports than for imports. This is not the case, as estimations of export unit values (reported in an earlier version of this paper) indicate.

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 imports within the two weeks, $w$ and $w+1$.[34] Out of these sets of product-country pairs, we compute the share with zero imports in the calendar year before $w$. This share of *entrants* is plotted in the top panel of Figure 6 (fat solid line). Also, a corresponding thin dashed line is added as reference 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 imports within the calendar year preceding $w$. Out of these pairs, we compute the share with zero imports in the two weeks, $w$ and $w+1$. This share of *temporary exiting pairs* is plotted in the bottom panel of Figure 6 (fat solid line). A corresponding thin dashed line is added as reference for the preceding year. Again, the figure does not indicate unusual exits around the date of the shock.

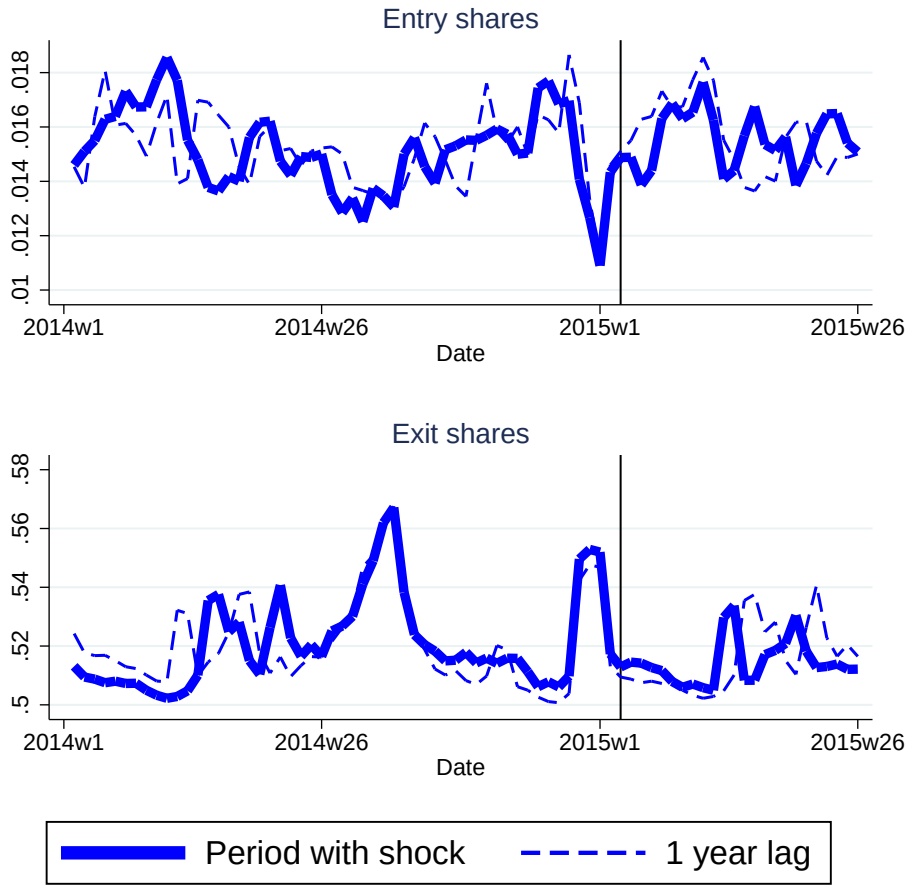
Clearly, we cannot observe all exits and entries of firms or products. Yet, the set of exits and entrants that can be identified (those plotted in Figure 6) do not indicate that unusual entrance or exit happen in the period after the shock within which the adjustment takes place.

Having discussed the potential effects of the two most relevant biases of exchange rate pass-through into unit values, we conclude that a large part of the sharp and sudden fall in 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 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 et al. (2014) show that import-intensive exporters display relatively low export price pass-through. Clearly, some firms

[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.

Figure 6: Entry and (temporary) exit shares at the weekly frequency




Entry (exit) shares are the shares of pairs that are active (not active) in the two weeks window [w,w+1] but not active (active) in the last 52 weeks [w-1,w-52].

might have adjusted their price one-to-one with the exchange rate, while 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 firm's 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 for goods invoiced in Swiss francs is driven by underlying nominal price changes. In particular, we read this findings as strong evidence of a prompt price adjustment in response to a large shock to the Swiss franc on January 15, 2015.[35] We claim that the price adjustment is clustered in that an uncommonly high share of firms adjust their prices. The systematic adjustments take place within the first two weeks after the shock. Presuming conservatively that prices either remain unadjusted or adjust 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). In the medium-run (months 4 to 6) the according pass-through is 0.61. This means that under the same assumptions 82% of those prices that were adjusted in the medium-run were adjusted immediately ($0.50/0.61 = 0.82$).

Our claim that the share of price adjustments in the sample of Swiss francs invoiced products increased after the January 15 shock is corroborated by directly observed price data. Figure 7 plots the year-on-year change of shares of price changes within the sample of import prices surveyed by the Federal Statistical Office to construct the Swiss import price index.[36] These price data are surveyed within the first eight days of each month and are reported at the monthly frequency, so that January 2015 data refer to the period before the shock. The top panel corresponds to the sample invoiced in Swiss francs and reveals a sharp increase in the frequency of price changes in February 2015 with a slight lull in March 2015 followed by an increase in the frequency in April 2015. Thereafter, the pattern of price changes returns to its pre shock level.[37] We attribute the staggered increase in the reported frequency of price changes to the fact that the Federal Statistical Office conducts its monthly survey on a changing sample of products. Therefore, some prices that were changed immediately after the exchange rate shock on January 15 were not surveyed before March or April. The corresponding price changes therefore appear in the statistics with a delay. The bottom panel plots the corresponding shares of price changes for the sample of goods

[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] We take year-on-year changes because the sample of prices is specific to each month of the year. Note that the sample includes goods from all partners and not just from the euro area.

[37] The average price change for import prices invoiced in Swiss francs (foreign currency) was 21.7% (10.0%) in the period from 2011 to 2014 and averaged 28.2% (10.3%) for the first six months in 2015.

invoiced in foreign currency.[38] In line with our earlier finding, the increase in the share of price changes is much more moderate for the sample of goods invoiced in foreign currencies. We acknowledge that the data underlying Figure 7 are only partially comparable to those used in our full analysis. Nevertheless, we read the above observations as qualitatively supporting evidence of our preferred interpretation of our central analytical findings.

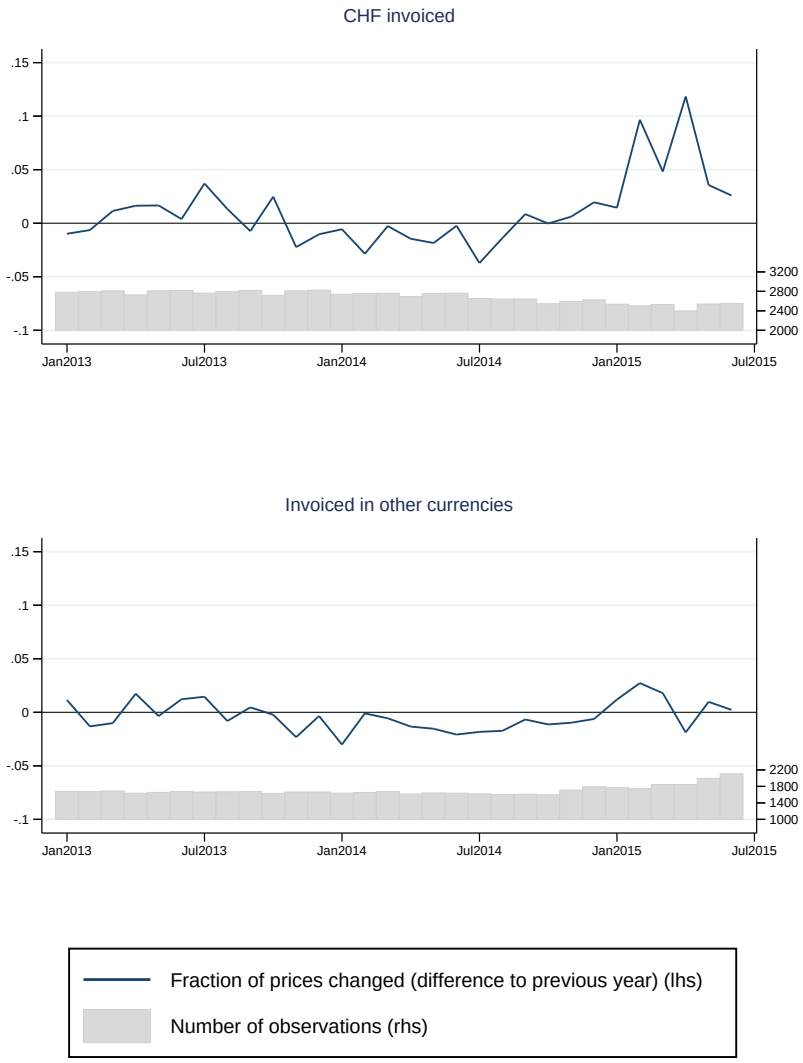
Our interpretation of fast price adjustments, in turn, implies that nominal rigidities play a minor role for the period immediately following the exchange rate shock. The findings reported above thus constitute strong evidence in favor of state-dependent pricing frameworks à la Dotsey et al. (1999) and 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. Our findings thus complement Alvarez et al. (2016), who show that the exchange rate pass-through materializes faster in response to large exchange rate shocks than to small shocks. Also, we connect to 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 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."[39] 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

[38] Specifically, this sample also includes goods invoiced in USD and other foreign currencies and covers all partner countries.

[39] 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.

Figure 7: Annual difference in the monthly price changes in import prices invoiced in Swiss francs




Source: Federal Statistical Office (IPI/PPI section), own calculations.

long run (see Gopinath et al. (2010)).[40] 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.

A question that remains open so far is how the fast adjustment of border 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.[41] In an attempt to address this question, we turn to informal information obtained through interviews conducted by delegates of the SNB regional network.[42] The interviews revealed that Swiss managers did 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.[43]

[40] Figure II in Gopinath and Rigobon (2008) suggests a cumulative 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).

[41] See Amiti and Weinstein (2011).

[42] 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.

[43] 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

# 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. The robustness checks show that our speed result holds for numerous subsamples of the dataset. The pass-through for goods invoiced in Swiss francs is always fast: in all robustness checks it reaches the medium-run pass-through within 14 working days at most. The most important restrictions 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. These robustness checks are based on specification (2) and are summarized in Table 2. The corresponding graphs of the daily price dynamics are relegated to Appendix 3.

Because our main attention concerns the start and the end day of the exchange rate pass-through, and given that these dates can only be sensibly defined for transactions that are invoiced in Swiss francs, the results presented in Table 2 are limited to this subset of observations. In other words, we investigate the robustness of our results presented in the bottom panel of Figure 5.

## 4.1 Unit values versus unit prices

A common critique of analyses based on unit values is that these measures constitute not only an imprecise but a 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).[44] 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, row 1.a in the upper panel of Table 2 presents the results for Swiss franc-invoiced imports

the exchange rate shock were unusually fast.

[44] 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.

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. | 1.a Baseline | 2 | 8 | 0.317 | 0.496 | 0.611 | 8608987 |
| | 2.a Big imp. | 11 | 11 | 0.291 | 0.291 | 0.373 | 1479497 |
| | 3.a Value > 300 | 3 | 12 | 0.182 | 0.262 | 0.410 | 3306882 |
| | 4.a Value < 300 | 2 | 7 | 0.370 | 0.604 | 0.722 | 5164283 |
| | 5.a Consump. goods | 2 | 7 | 0.495 | 0.645 | 0.737 | 4489635 |
| | 6.a Invest. goods | 5 | 8 | 0.259 | 0.375 | 0.475 | 4086848 |
| | 7.a Interm. goods | 2 | 6 | 0.288 | 0.419 | 0.592 | 1846683 |
| | 8.a Diff. goods | 2 | 8 | 0.301 | 0.510 | 0.596 | 7699835 |
| | 9.a Ref. priced | 2 | 5 | 0.275 | 0.530 | 0.634 | 614535 |
| | 10.a Org. exchange | 5 | 7 | 0.454 | 0.609 | 0.919 | 53826 |
| | 11.a Single trans. | 2 | 2 | 0.470 | 0.470 | 0.508 | 2165627 |
| | 12.a Transportation by road | 1 | 12 | 0.082 | 0.532 | 0.627 | 7788390 |
| | 13.a Imports from the US | 3 | 8 | 0.832 | 1.013 | 1.125 | 657763 |
| Sup. units | 1.b Baseline | 2 | 9 | 0.381 | 0.621 | 0.580 | 2274015 |
| | 2.b Big imp. | 10 | 14 | -0.318 | 0.334 | 0.476 | 516469 |
| | 3.b Value > 300 | 4 | 12 | 0.222 | 0.314 | 0.379 | 1062995 |
| | 4.b Value < 300 | 2 | 7 | 0.471 | 0.545 | 0.755 | 1165622 |
| | 5.b Consump. goods | 2 | 9 | 0.592 | 0.639 | 0.809 | 1437471 |
| | 6.b Invest. goods | 6 | 6 | 0.421 | 0.421 | 0.208 | 813982 |
| | 7.b Interm. goods | 1 | 1 | 0.437 | 0.437 | 0.483 | 224350 |
| | 11.b Single trans. | 2 | 2 | 0.361 | 0.361 | 0.421 | 656835 |
| | 12.b Transportation by road | 1 | 9 | 0.155 | 0.684 | 0.623 | 1980756 |

Note: all regressions include augmented 8-digit HS code - country - postal code fixed effects and a 2-digit 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. All medium run pass-through are significant at the 5% level. Regression results are shown for unit values (All obs.) as well as for prices (i.e. for the subsample for which supplementary units are available). The baseline specification is the one described in Section 3.2. The following subsamples are used for each of the other specifications presented in this table: 2. the 8-digits HS code - postal code combinations which have the largest shares of total imports and whose collective share is larger than two-thirds; 3. transactions with a value larger than CHF 300; 4. transactions with a value smaller than CHF 300; 5. 8-digit HS codes classified as a consumption goods (Swiss Customs Administration classifcation); 6. 8-digit HS codes classified as a investment goods (Swiss Customs Administration classifcation); 7. 8-digit HS codes classified as a intermediate goods (Broad Economic Categories (BEC) classification); 8. differentiated goods (Rauch (1999) classification); 9. Reference priced goods (Rauch (1999) classification); 10. Goods traded on an organised exchange (Rauch (1999) classification); 11. customs declarations with one single transaction; 12. transactions of goods transported by road; 13. imports from the United-States.

and shows that the baseline regression for imports invoiced in Swiss francs results in a statistically significant pass-through of 0.32 after two working days and a medium-run pass-through of 0.61 attained after eight working days. The corresponding estimates based on unit prices (row 1.b in the bottom panel) show a similar start day and imply that the medium-run pass-through is reached after nine 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 our estimations. Berman et al. (2012) show that highly productive firms absorb more of the exchange rate shocks through export prices and thus exhibit a lower pass-through into import prices. Consistently, Amiti et al. (2014) show that import prices of large, import intensive firms exhibit a lower exchange rate pass-through as part of their production costs vary with foreign inputs.[45] Equivalently, the speed of response to the shock may differ by firm size and import intensity.

While we cannot control for firm characteristics, we nevertheless try to exclude a large share of small importers. Specifically, we restrict the sample of import transactions to pairs of 8-digit HS code and ZIP-code with the largest import value. This criterion constitutes only a rough proxy for firm size, but it does exclude many small Swiss importers. The results are given in rows 2.a and 2.b in Table 2 and show that the speed of adjustment of 11 working days is fast for big importers, too.[46]

A second and additional way to proxy for firm size is by separating transactions of large value from transactions of low value.[47] 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.[48] Restrictions 3 and 4 in Table 2 show that the medium-run pass-through into import unit values is lower for big shipments and higher for small ones. The estimations also show that, again, no notable differences are observed for the start and end dates.

### 4.3 Intermediate, investment and consumption goods

One of the limitations of our data is that intrafirm transactions are 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 cumulative pass-through reported in Neiman (2010) displays a similar lack

[45] See also Chung (2016) on the currency choice of import-intensive firms.

[46] In Appendix 3, Figure 10 shows the daily results for imports of big importers.

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

[48] 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 3, Figure 11 shows the daily results for the import unit values of transactions of less than CHF 300. Figure 12 shows the daily results for the import unit values of transactions of more than CHF 300.

of immediate adjustment for both intrafirm and arm's length transactions. Nevertheless, it might still be suspected that our fast adjustment results from multinational firms quickly adjusting their transfer prices.[49] 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 goods categories: consumption goods, investment goods and raw materials, and intermediate goods.[50] Restrictions 5, 6, and 7 in Table 2 show the start and end days with the pass-through estimates for consumption (restriction 5), investment goods and raw materials (restriction 6), and intermediate goods (restriction 7).[51] Some heterogeneity in the medium-run level of pass-through is uncovered, but again, the results show that the adjustment starts rapidly and reaches its medium-run pass-through estimate within nine working 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) classification, Gopinath and Rigobon (2008) report that the median import price duration is substantially longer 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.[52] The results,

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

[50] 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.

[51] In Appendix 3, Figure 14 shows the daily estimates on import unit values for the investment goods and raw material, Figure 13 presents those for consumption goods and Figure 15 those for intermediate goods.

[52] 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.

presented in rows 8.a to 10.a 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 medium-run 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 in unit values the second working day after the shock and reach their medium-term level after eight working days.[53]

### 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 focusing on customs declaration with a single transaction only. The results are listed as restrictions 11.a and 11.b in Table 2. Consistent with some currency misclassification, they show a lower pass-through than the full sample. They show however that the speed of adjustment is fast even in those cases where currency misclassification is impossible, as the medium-run pass-through is reached after only a few days in both cases.[54]

### 4.6 Product category regressions

We also investigate whether the speed of price adjustment differs across HS categories by running separate regressions for each HS section. Table 3

[53] In Appendix 3, Figure 16 shows the daily estimates on 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.

[54] In Appendix 3, Figure 17 show the daily results for transactions where currency misclassification is not possible for imports.

presents the section specific results, which 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.[55]

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 |

Note: 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. All medium run pass-through are significant at the 5% level unless marked with a +.

## 4.7 The role of distance

Finally, Swiss trade with the euro area may be considered as rather special due to the geographical proximity and the various bilateral agreements between both economies. The proximity, in particular, could drive fast price adjustment, as delivery time is reduced to a minimum between neighboring economies and corresponding contracts may be written short term.

To address concerns related to distance and delivery time, we perform two additional robustness checks. First, we restrict the sample of our baseline specification to goods that are transported by truck. We thus exclude goods that are transported by plane and which are characterized by a par-

[55] In Appendix 3, Figure 18 shows the median of the section specific daily point estimates and confidence intervals.

ticularly short delivery time, thus potentially driving the fast reaction of prices.[56] The results are reported in Figure 19 and show that estimates with the restricted sample do not alter the results. Point estimates and error bands are slightly smaller than those in the baseline specification (compare Figure 5) and the pass-through starts on January 16th and reaches its medium-run level 12 working days after the shock.

For the second robustness check, we rerun our daily regressions for Swiss imports from the United States. The size of the sample for this specification shrinks by an order of magnitude, since between January 2014 to June 2015 imports from the United States account for 6.5% of all Swiss imports (instead of the 64.4% for the euro area). Moreover, there are now three samples defined by invoicing currencies (Swiss franc, euro, and U.S. dollar), which further reduces the size of each individual sample.[57]

The results are reported in Figure 20 in the Appendix and summarized in row 13.a in Table 2 for the sample of Swiss franc invoiced goods. While the point estimates of the daily dummies are less precisely estimated, the overall message of the baseline specification remains unchanged. Unit values of goods invoiced in U.S. dollar and euro react mechanically and instantaneously (see top and the middle panel of the figure). Importantly, unit values of goods invoiced in Swiss francs react significantly on the third working day after the exchange rate shock and reach the medium-run level after five additional working days (see bottom panel of the figure). Again, we find that within the sample of goods invoiced in Swiss francs, nominal prices seem to react promptly. This finding reported for imports from the United States suggests, in particular, that swift price adjustment is not limited to geographically close trade partners.

# 5 Conclusion

This paper analyzes the speed of exchange rate pass-through for tradable goods to an unusually large exchange rate shock at the daily frequency. This high frequency setup allows us to precisely track the dynamics of pass-through into import prices. The exogenous shock originates from the SNB's decision to lift the minimum exchange rate policy, which resulted in a perma-

[56] This restriction reduces the number of observations to 80.8% of its original size in terms of import values. Goods transported by plane and by train account for 7.0% and 6.2% of import values, respectively; according regressions render excessively large error bands.

[57] In terms of import values, the respective shares are 11.9% for Swiss francs, 26.6% for euro and 60.2% for U.S. dollars.

nent appreciation of the Swiss franc of more than 11% against the euro. Our main findings are twofold. First, the pass-through is immediate and complete for goods invoiced in euro. This finding is consistent with the view that no systematic nominal price adjustment takes place for imports invoiced in foreign currency, as shown by Gopinath et al. (2010) and Gopinath (2015). We thus generalize these earlier findings to the case of a small open economy and to a large shock. Second, for goods invoiced in Swiss francs the pass-through is partial and particularly fast: it starts on the second working day after the exchange rate shock and reaches the medium-run pass-through after eight working days. Although the rate of pass-through is not uniform across various subsets of product groups, we show that the speed of adjustment is broadly homogenous. In our interpretation, this second finding constitutes evidence in favor of fast nominal price adjustment.

Formulating the synthesis of both findings, we suggest that whenever a firm adjusted its border price in reaction to the large exchange rate shock, it did so very quickly. We view this fact as a novelty and as our main contribution to the literature. We further argue that it suggests that nominal rigidities unravel quickly in the face of large exchange rate shocks.

Our results have two important implications. First, international firms seem to demonstrate a high level of price flexibility in their ability to respond to large sudden changes in their operating environment. Our findings thus tend to support state-dependent pricing models by Dotsey et al. (1999) as opposed to time-dependent pricing models by Calvo (1983). Second, price adjustments seem to strongly depend 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. These observations may turn out to be crucial for the modeling of price setting behavior and the forecasting of import and export prices in an economic environment characterized by 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? In *NBER Macroeconomics Annual 2016, Volume 31*. University of Chicago Press.

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.

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 (2016, May). Quality, trade, and exchange rate pass-through. *Journal of International Economics 100*, 61–80.

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

Chung, W. (2016). Imported inputs and invoicing currency choice: Theory and evidence from uk transaction data. *Journal of International Economics 99*, 237–250.

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. *Brazilian Review of Econometrics*. Forthcoming.

Flach, L. (2016). Quality upgrading and price heterogeneity: evidence from Brazilian exporters. *Journal of International Economics*.

Forbes, K., I. M. Hjortsoe, and T. Nenova (2015). The shocks matter: improving our estimates of exchange rate pass-through. *External MPC Unit Discussion Paper* (43).

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. Working Paper 21646, 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 (2016). Price setting in online markets: Basic facts, international comparisons, and cross-border integration. *American Economic Review*. Forthcoming.

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

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

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.

# Appendix 1: Tables

Table 4: Shares of invoicing currency for imports from the euro area by 2-digit HS code

| 2-digit HS code | Based on transactions | | | | Based on value | | | |
|---|---|---|---|---|---|---|---|---|
| | Share in tot. imports [%] | Invoicing currency shares | | | Share in tot. imports [%] | Invoicing currency shares | | |
| | | CHF | EURO | Other | | CHF | EURO | Other |
| 01 | 0.08 | 0.16 | 0.84 | 0.00 | 0.08 | 0.11 | 0.89 | 0.00 |
| 02 | 0.39 | 0.13 | 0.87 | 0.00 | 0.29 | 0.12 | 0.87 | 0.01 |
| 03 | 0.45 | 0.06 | 0.92 | 0.02 | 0.21 | 0.09 | 0.87 | 0.04 |
| 04 | 0.56 | 0.05 | 0.95 | 0.00 | 0.47 | 0.04 | 0.96 | 0.00 |
| 05 | 0.05 | 0.25 | 0.74 | 0.00 | 0.04 | 0.03 | 0.97 | 0.00 |
| 06 | 1.36 | 0.32 | 0.68 | 0.00 | 0.47 | 0.23 | 0.77 | 0.00 |
| 07 | 1.84 | 0.17 | 0.83 | 0.00 | 0.43 | 0.14 | 0.86 | 0.00 |
| 08 | 0.86 | 0.13 | 0.87 | 0.00 | 0.54 | 0.06 | 0.93 | 0.01 |
| 09 | 0.26 | 0.18 | 0.82 | 0.00 | 0.13 | 0.06 | 0.92 | 0.02 |
| 10 | 0.12 | 0.24 | 0.76 | 0.00 | 0.21 | 0.46 | 0.54 | 0.00 |
| 11 | 0.11 | 0.08 | 0.92 | 0.00 | 0.07 | 0.04 | 0.96 | 0.00 |
| 12 | 0.33 | 0.33 | 0.67 | 0.00 | 0.16 | 0.29 | 0.71 | 0.00 |
| 13 | 0.03 | 0.20 | 0.79 | 0.01 | 0.04 | 0.07 | 0.90 | 0.03 |
| 14 | 0.01 | 0.11 | 0.89 | 0.00 | 0.00 | 0.18 | 0.81 | 0.01 |
| 15 | 0.20 | 0.19 | 0.81 | 0.00 | 0.16 | 0.07 | 0.91 | 0.02 |
| 16 | 0.37 | 0.18 | 0.80 | 0.01 | 0.20 | 0.27 | 0.70 | 0.03 |
| 17 | 0.50 | 0.29 | 0.70 | 0.00 | 0.19 | 0.13 | 0.86 | 0.01 |
| 18 | 0.91 | 0.71 | 0.29 | 0.00 | 0.37 | 0.36 | 0.47 | 0.18 |
| 19 | 1.55 | 0.24 | 0.75 | 0.00 | 0.59 | 0.22 | 0.78 | 0.00 |
| 20 | 0.83 | 0.20 | 0.80 | 0.00 | 0.28 | 0.16 | 0.81 | 0.02 |
| 21 | 1.48 | 0.56 | 0.44 | 0.00 | 0.45 | 0.18 | 0.82 | 0.00 |
| 22 | 1.50 | 0.25 | 0.75 | 0.00 | 1.36 | 0.16 | 0.83 | 0.00 |
| 23 | 0.29 | 0.29 | 0.71 | 0.00 | 0.24 | 0.26 | 0.72 | 0.02 |
| 24 | 0.06 | 0.58 | 0.36 | 0.06 | 0.09 | 0.17 | 0.36 | 0.47 |
| 25 | 0.56 | 0.22 | 0.77 | 0.00 | 0.33 | 0.28 | 0.72 | 0.01 |
| 26 | 0.04 | 0.02 | 0.98 | 0.00 | 0.02 | 0.09 | 0.91 | 0.00 |
| 27 | 0.39 | 0.35 | 0.64 | 0.01 | 7.42 | 0.73 | 0.25 | 0.01 |
| 28 | 0.36 | 0.32 | 0.67 | 0.01 | 0.35 | 0.15 | 0.84 | 0.02 |
| 29 | 0.63 | 0.43 | 0.55 | 0.02 | 7.89 | 0.75 | 0.22 | 0.02 |
| 30 | 0.88 | 0.32 | 0.67 | 0.01 | 13.19 | 0.31 | 0.68 | 0.01 |
| 31 | 0.06 | 0.24 | 0.76 | 0.00 | 0.09 | 0.20 | 0.80 | 0.01 |
| 32 | 0.92 | 0.24 | 0.75 | 0.00 | 0.65 | 0.15 | 0.85 | 0.00 |
| 33 | 1.66 | 0.42 | 0.58 | 0.00 | 0.81 | 0.29 | 0.70 | 0.01 |
| 34 | 1.10 | 0.29 | 0.71 | 0.00 | 0.43 | 0.15 | 0.84 | 0.00 |
| 35 | 0.27 | 0.24 | 0.76 | 0.00 | 0.16 | 0.10 | 0.90 | 0.00 |
| 36 | 0.01 | 0.22 | 0.76 | 0.01 | 0.02 | 0.05 | 0.94 | 0.01 |
| 37 | 0.06 | 0.28 | 0.70 | 0.02 | 0.04 | 0.26 | 0.72 | 0.02 |
| 38 | 1.58 | 0.29 | 0.70 | 0.01 | 1.00 | 0.26 | 0.71 | 0.03 |
| 39 | 5.63 | 0.27 | 0.73 | 0.01 | 4.38 | 0.13 | 0.86 | 0.00 |
| 40 | 1.64 | 0.36 | 0.62 | 0.02 | 0.79 | 0.32 | 0.68 | 0.00 |
| 41 | 0.04 | 0.11 | 0.89 | 0.00 | 0.06 | 0.03 | 0.97 | 0.00 |
| 42 | 1.44 | 0.36 | 0.63 | 0.01 | 0.48 | 0.23 | 0.71 | 0.06 |
| 43 | 0.04 | 0.33 | 0.67 | 0.01 | 0.02 | 0.33 | 0.65 | 0.02 |
| 44 | 1.26 | 0.21 | 0.79 | 0.00 | 1.33 | 0.14 | 0.86 | 0.00 |
| 45 | 0.03 | 0.20 | 0.79 | 0.01 | 0.03 | 0.11 | 0.88 | 0.00 |
| 46 | 0.05 | 0.20 | 0.80 | 0.00 | 0.00 | 0.10 | 0.89 | 0.00 |
| 47 | 0.07 | 0.03 | 0.97 | 0.01 | 0.07 | 0.00 | 0.93 | 0.07 |
| 48 | 2.21 | 0.25 | 0.75 | 0.00 | 1.59 | 0.21 | 0.79 | 0.00 |
| 49 | 3.34 | 0.50 | 0.49 | 0.01 | 1.24 | 0.31 | 0.69 | 0.00 |
| 50 | 0.03 | 0.13 | 0.86 | 0.00 | 0.01 | 0.04 | 0.96 | 0.00 |

Continued on next page

Table 4 – continued from previous page

| 2-digit HS code | Based on transactions | | | | Based on value | | | |
|---|---|---|---|---|---|---|---|---|
| | Share in tot. imports [%] | Invoicing currency shares | | | Share in tot. imports [%] | Invoicing currency shares | | |
| | | CHF | EURO | Other | | CHF | EURO | Other |
| 51 | 0.09 | 0.15 | 0.84 | 0.01 | 0.07 | 0.06 | 0.94 | 0.00 |
| 52 | 0.20 | 0.20 | 0.80 | 0.00 | 0.12 | 0.32 | 0.68 | 0.00 |
| 53 | 0.05 | 0.21 | 0.79 | 0.00 | 0.01 | 0.22 | 0.78 | 0.00 |
| 54 | 0.16 | 0.17 | 0.83 | 0.00 | 0.13 | 0.07 | 0.93 | 0.00 |
| 55 | 0.13 | 0.20 | 0.80 | 0.00 | 0.06 | 0.08 | 0.88 | 0.05 |
| 56 | 0.32 | 0.19 | 0.81 | 0.00 | 0.17 | 0.07 | 0.92 | 0.00 |
| 57 | 0.33 | 0.33 | 0.67 | 0.00 | 0.10 | 0.30 | 0.70 | 0.00 |
| 58 | 0.19 | 0.23 | 0.77 | 0.00 | 0.04 | 0.15 | 0.85 | 0.00 |
| 59 | 0.20 | 0.26 | 0.74 | 0.00 | 0.11 | 0.19 | 0.81 | 0.00 |
| 60 | 0.11 | 0.09 | 0.91 | 0.00 | 0.05 | 0.05 | 0.95 | 0.00 |
| 61 | 4.26 | 0.35 | 0.65 | 0.00 | 0.52 | 0.31 | 0.68 | 0.01 |
| 62 | 3.77 | 0.34 | 0.66 | 0.00 | 0.72 | 0.23 | 0.75 | 0.01 |
| 63 | 1.23 | 0.32 | 0.67 | 0.00 | 0.28 | 0.16 | 0.84 | 0.00 |
| 64 | 2.16 | 0.27 | 0.72 | 0.00 | 0.59 | 0.16 | 0.82 | 0.02 |
| 65 | 0.27 | 0.37 | 0.63 | 0.00 | 0.04 | 0.19 | 0.81 | 0.01 |
| 66 | 0.07 | 0.27 | 0.73 | 0.00 | 0.01 | 0.19 | 0.81 | 0.00 |
| 67 | 0.10 | 0.33 | 0.67 | 0.00 | 0.01 | 0.35 | 0.64 | 0.01 |
| 68 | 1.01 | 0.20 | 0.80 | 0.00 | 0.65 | 0.17 | 0.82 | 0.00 |
| 69 | 0.84 | 0.18 | 0.81 | 0.00 | 0.39 | 0.12 | 0.88 | 0.00 |
| 70 | 1.26 | 0.37 | 0.62 | 0.01 | 0.70 | 0.15 | 0.84 | 0.00 |
| 71 | 0.55 | 0.35 | 0.64 | 0.01 | 3.74 | 0.31 | 0.64 | 0.05 |
| 72 | 0.88 | 0.22 | 0.78 | 0.00 | 1.98 | 0.16 | 0.84 | 0.00 |
| 73 | 3.98 | 0.28 | 0.71 | 0.01 | 2.44 | 0.12 | 0.88 | 0.00 |
| 74 | 0.40 | 0.24 | 0.75 | 0.01 | 0.73 | 0.11 | 0.85 | 0.04 |
| 75 | 0.01 | 0.13 | 0.85 | 0.02 | 0.05 | 0.04 | 0.95 | 0.01 |
| 76 | 1.07 | 0.19 | 0.81 | 0.01 | 1.62 | 0.12 | 0.87 | 0.01 |
| 78 | 0.01 | 0.29 | 0.71 | 0.00 | 0.01 | 0.02 | 0.98 | 0.00 |
| 79 | 0.04 | 0.22 | 0.75 | 0.02 | 0.04 | 0.21 | 0.61 | 0.18 |
| 80 | 0.01 | 0.26 | 0.73 | 0.00 | 0.01 | 0.09 | 0.82 | 0.09 |
| 81 | 0.05 | 0.18 | 0.80 | 0.02 | 0.08 | 0.06 | 0.89 | 0.05 |
| 82 | 1.73 | 0.30 | 0.70 | 0.00 | 0.64 | 0.15 | 0.85 | 0.00 |
| 83 | 1.21 | 0.33 | 0.66 | 0.01 | 0.49 | 0.19 | 0.80 | 0.00 |
| 84 | 9.21 | 0.28 | 0.70 | 0.02 | 10.32 | 0.14 | 0.83 | 0.03 |
| 85 | 9.59 | 0.35 | 0.63 | 0.02 | 5.71 | 0.22 | 0.75 | 0.03 |
| 86 | 0.08 | 0.11 | 0.89 | 0.00 | 0.59 | 0.10 | 0.90 | 0.00 |
| 87 | 4.60 | 0.54 | 0.45 | 0.02 | 8.49 | 0.60 | 0.39 | 0.00 |
| 88 | 0.10 | 0.10 | 0.58 | 0.32 | 0.49 | 0.11 | 0.38 | 0.50 |
| 89 | 0.01 | 0.14 | 0.85 | 0.01 | 0.06 | 0.03 | 0.95 | 0.02 |
| 90 | 3.86 | 0.37 | 0.61 | 0.01 | 3.52 | 0.26 | 0.72 | 0.02 |
| 91 | 0.40 | 0.36 | 0.63 | 0.01 | 1.28 | 0.27 | 0.72 | 0.01 |
| 92 | 0.11 | 0.36 | 0.64 | 0.00 | 0.04 | 0.31 | 0.68 | 0.01 |
| 93 | 0.03 | 0.12 | 0.88 | 0.00 | 0.07 | 0.13 | 0.86 | 0.00 |
| 94 | 4.33 | 0.17 | 0.82 | 0.00 | 2.73 | 0.12 | 0.88 | 0.01 |
| 95 | 1.55 | 0.51 | 0.49 | 0.00 | 0.35 | 0.21 | 0.78 | 0.01 |
| 96 | 1.04 | 0.29 | 0.70 | 0.00 | 0.30 | 0.37 | 0.62 | 0.00 |
| min | 0.01 | 0.02 | 0.29 | 0.00 | 0.00 | 0.00 | 0.22 | 0.00 |
| max | 9.59 | 0.71 | 0.98 | 0.32 | 13.19 | 0.75 | 0.98 | 0.50 |
| mean | 1.05 | 0.26 | 0.73 | 0.01 | 1.05 | 0.19 | 0.79 | 0.03 |
| median | 0.39 | 0.24 | 0.75 | 0.00 | 0.28 | 0.16 | 0.83 | 0.01 |

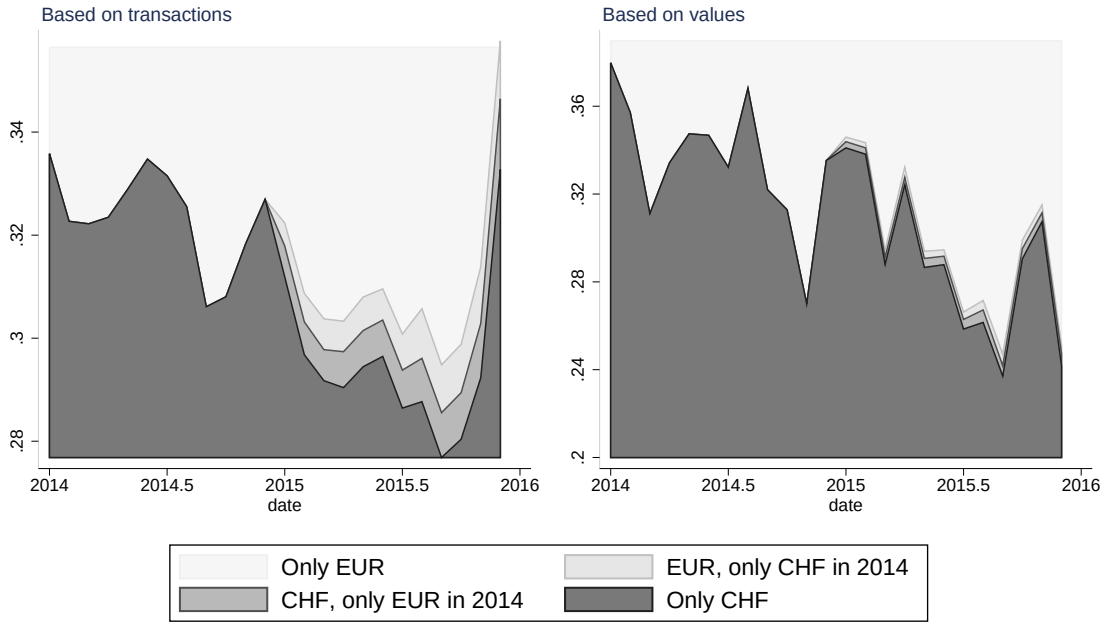
*Note*: the corresponding descriptions for the 2-digit HS codes can be found at http://xtares.admin.ch/tares/main/mainFormFiller.do;jsessionid=ng6ZXMrTJNhpKyd6TPZv3MGkLGzs8qTTqhbkv48GL7Cfs4Qn2XVL!91241224.

## Appendix 2: 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 imports. Two panels for the number of transactions and their value are presented. Each of these panels 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 for a firm is proxied by the triplet: postal code, HS product, and partner country.

The results show that the level of switching after January 15, 2015 is particularly low. It is less than 0.01% for both 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 imports from the euro area




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.

# Appendix 3: Graphs to the robustness checks

### 4.2 Graphs for proxying firm size

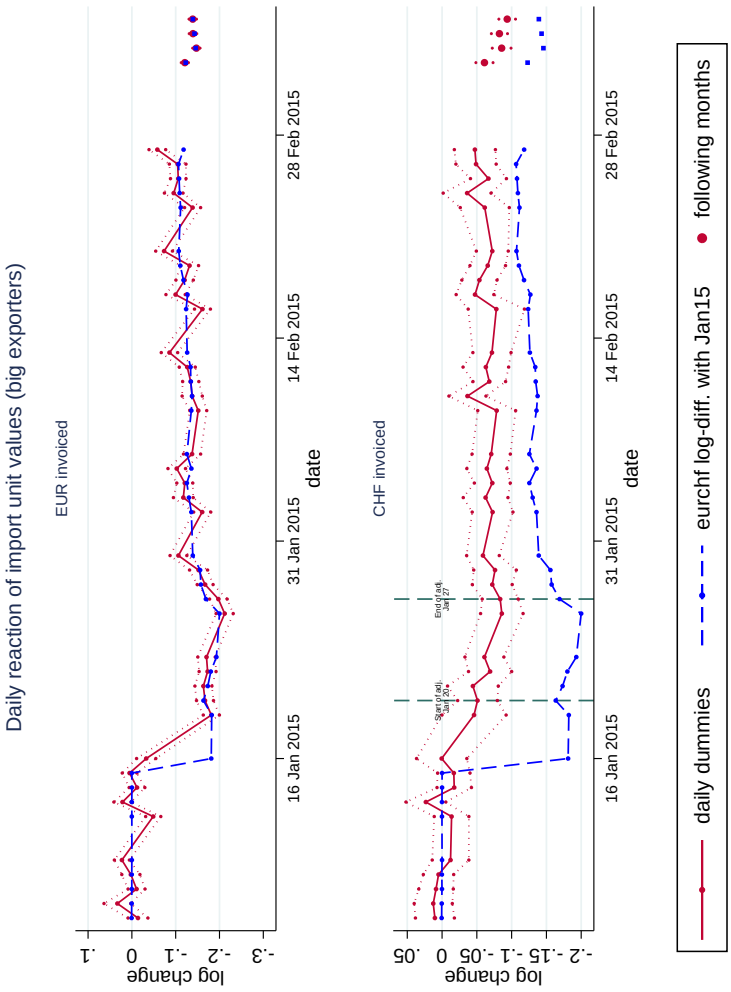



Figure 9: Daily dummies for import unit values from big HS-country export combinations (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a 2-digit HS -country specific trend. Error are clustered at the postal code level.

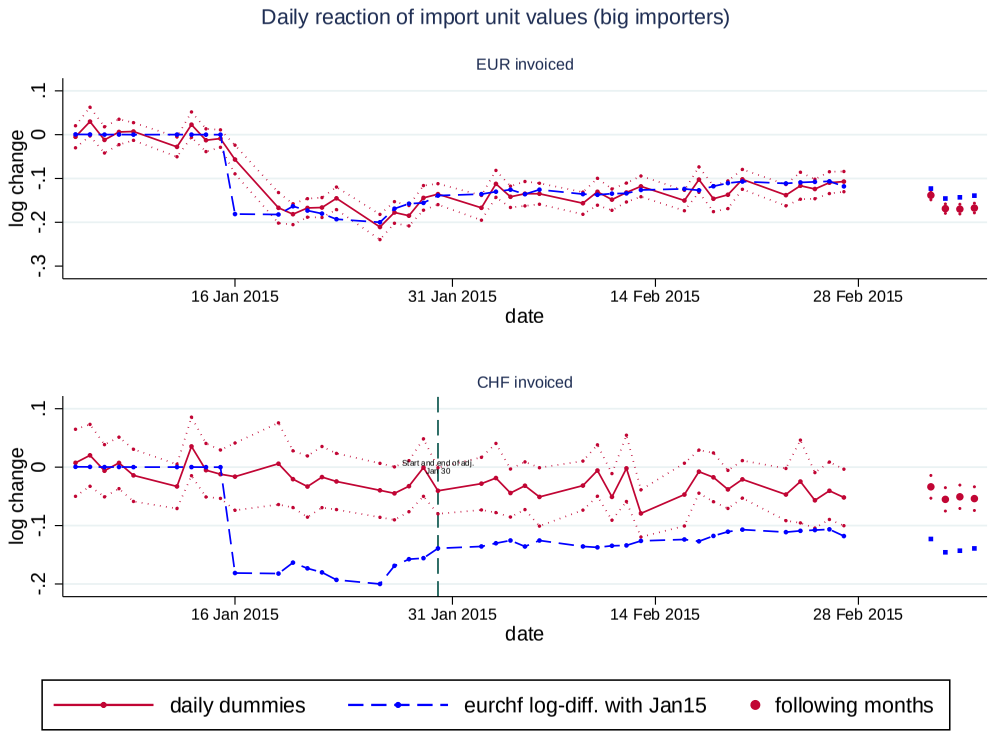



Figure 10: Daily dummies for import unit values of big HS-postal code importer combinations (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a 2-digit HS -country specific trend. Error are clustered at the postal code level.

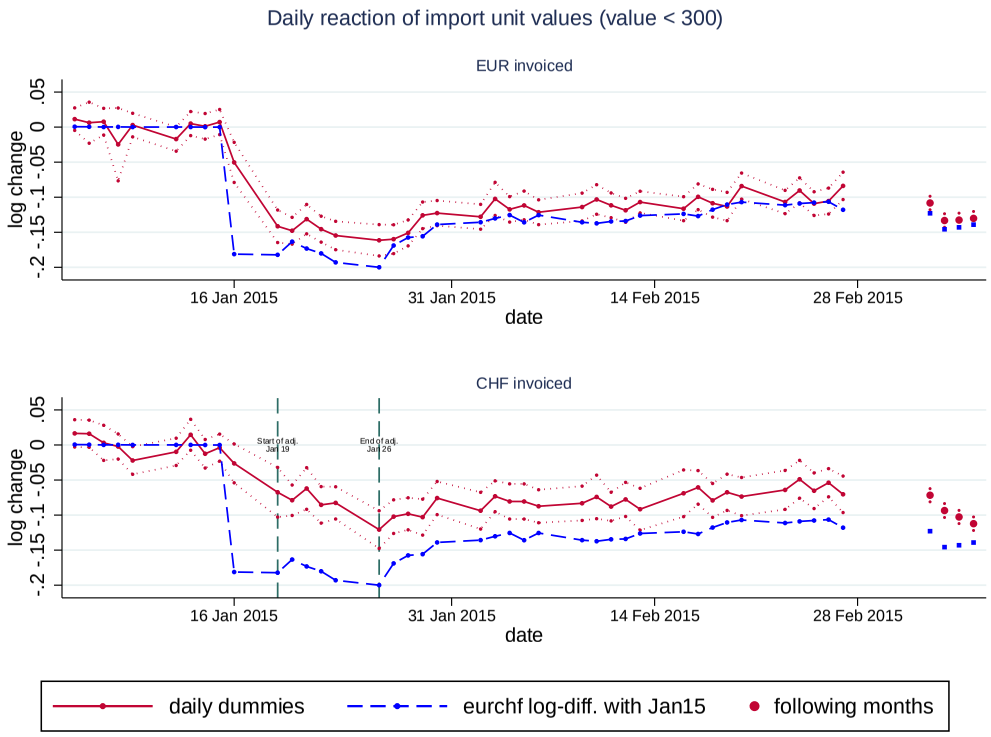



Figure 11: Daily dummies for import unit values for shipments worth less than CHF 300 (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a 2-digit HS -country specific trend. Errors are clustered at the postal code level.

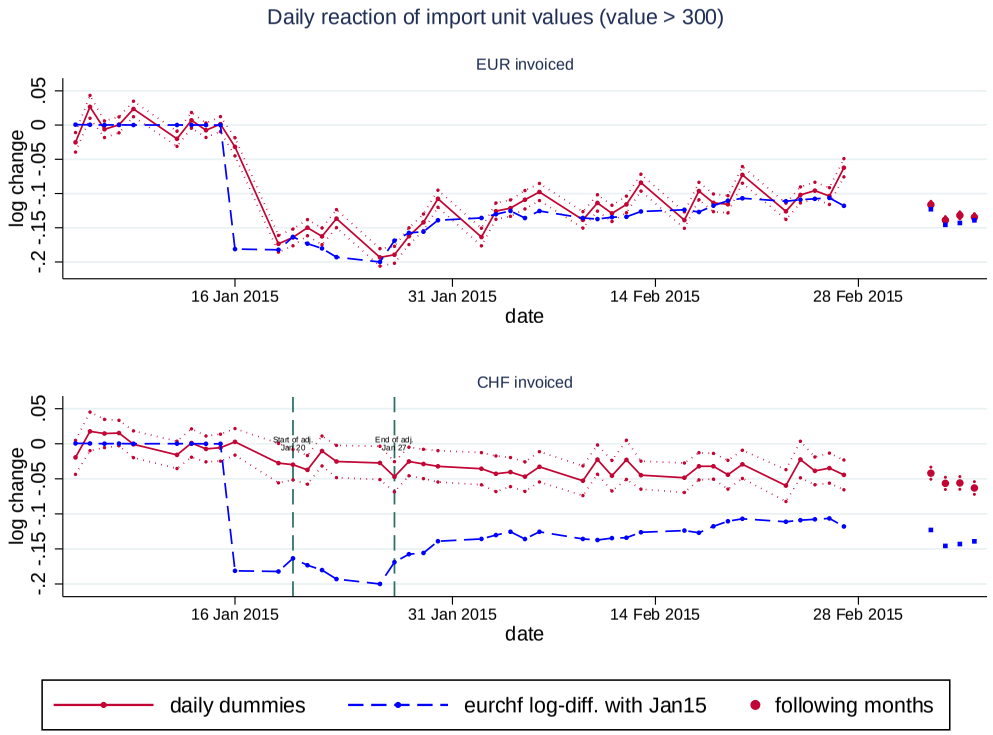



Figure 12: Daily dummies for import unit values for shipments worth more than CHF 300 (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a 2-digit HS-country specific trend. Errors are clustered at the postal code level.

### 4.3 Graphs for intermediate, investment and consumption goods

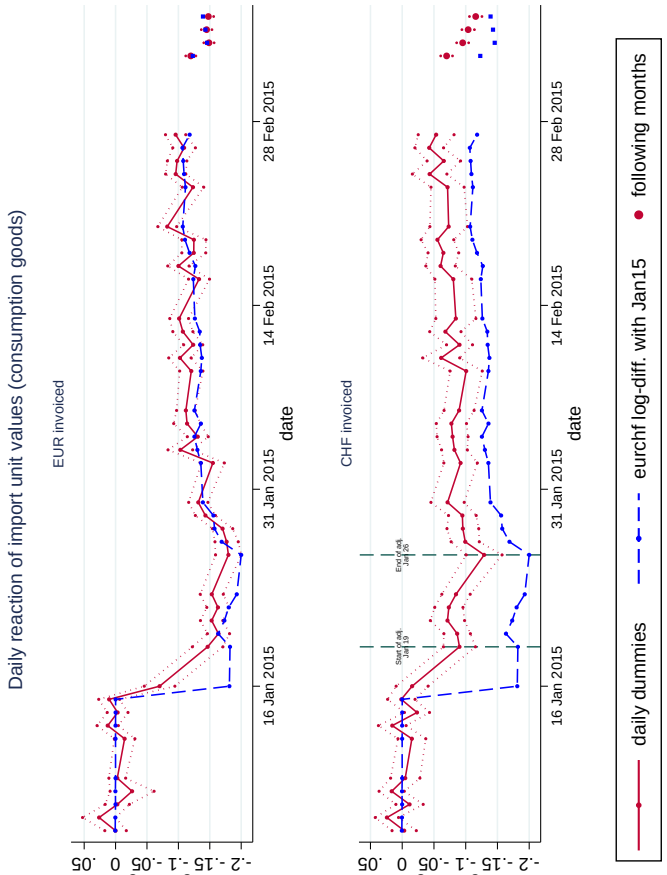



Figure 13: Daily dummies for import unit values for consumption goods (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a 2-digit HS -country specific trend. Errors are clustered at the postal code level.

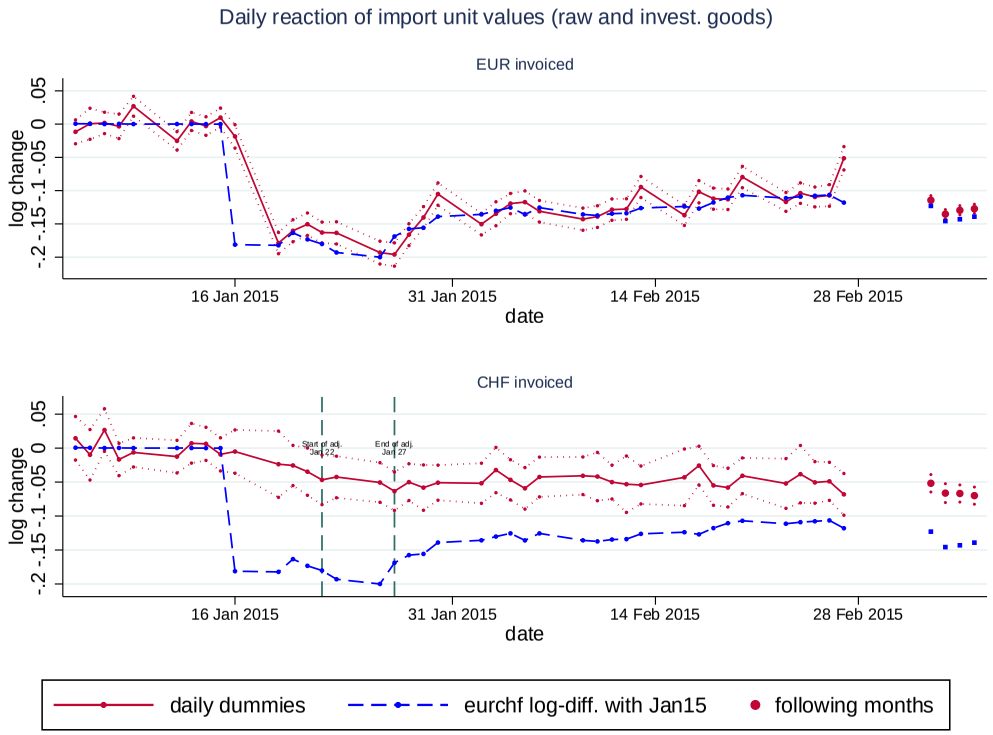



Figure 14: Daily dummies for import unit values for investment goods and raw materials (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a 2-digit HS-country specific trend. Errors are clustered at the postal code level.

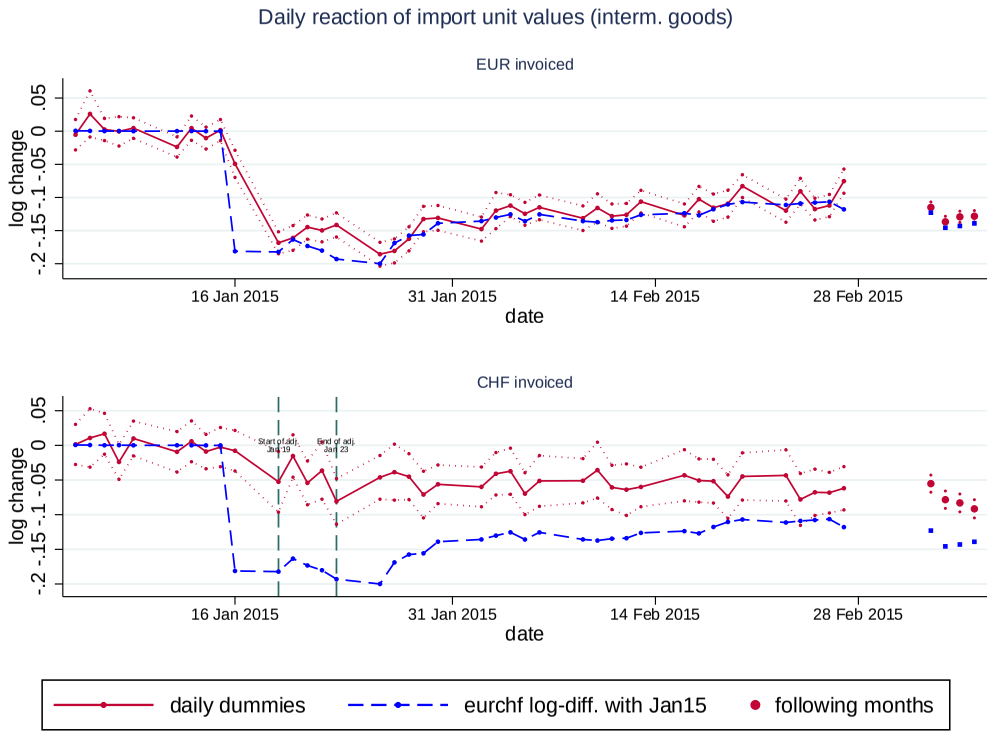



Figure 15: Daily dummies for import unit values for intermediate goods (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a 2-digit HS-country specific trend. Errors are clustered at the postal code level.

### 4.4 Graphs by Rauch classification

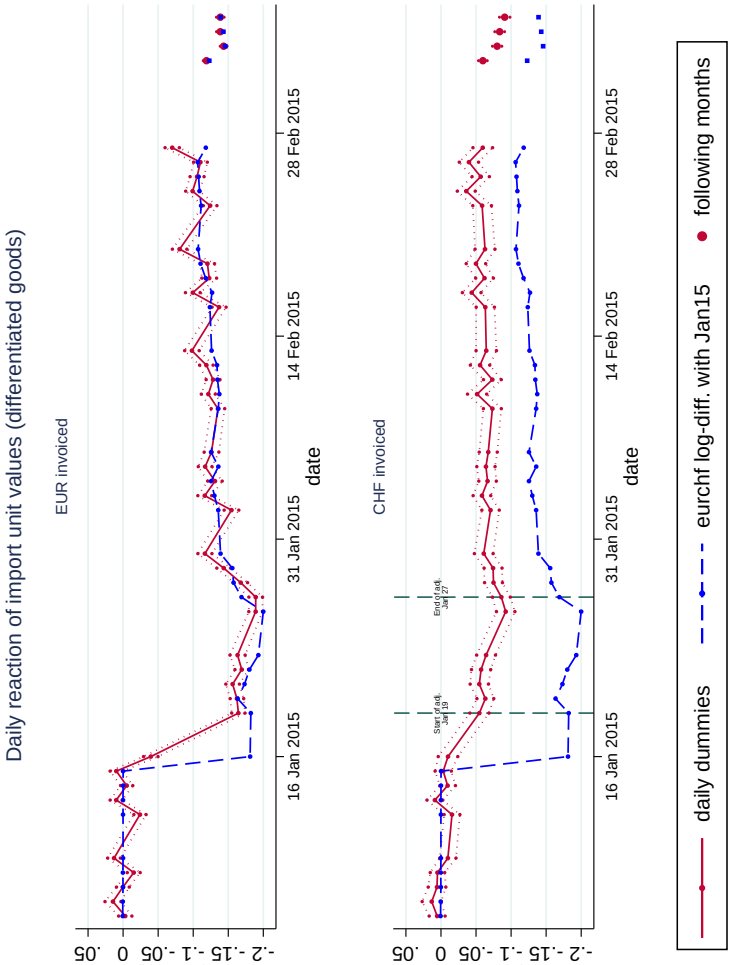



Figure 16: Daily dummies for import unit values of differentiated goods (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a 2-digit HS -country specific trend. Error are clustered at the postal code level.

### 4.5 Graphs for single item declarations

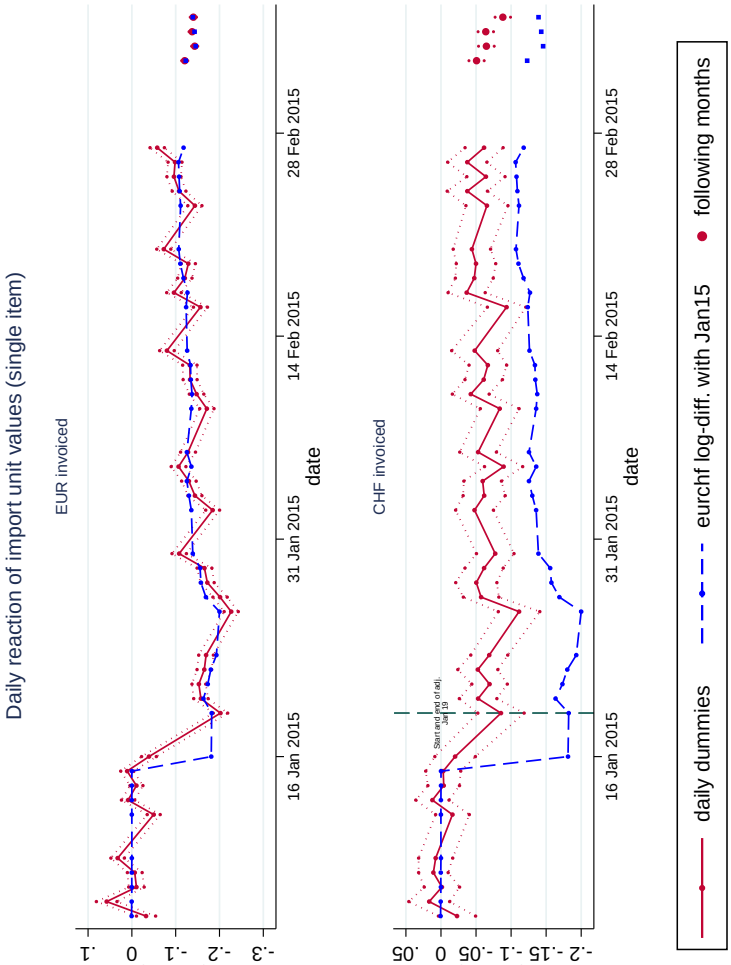



Figure 17: Daily dummies for import unit values when the transaction is unique in the custom declaration (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a 2-digit HS -country specific trend. Error are clustered at the postal code level.

### 4.6 Graphs for section-level regressions

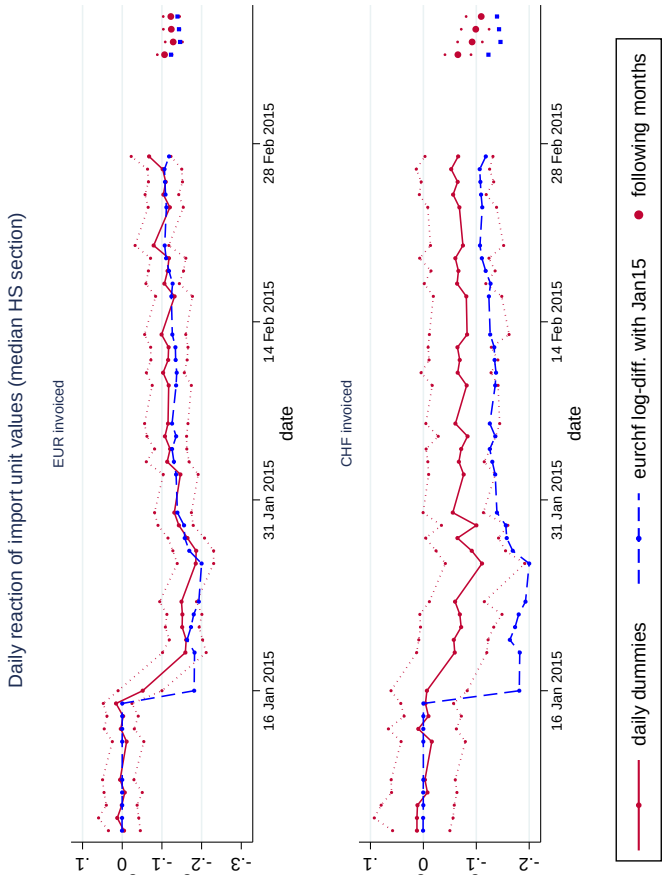



Figure 18: Median of each HS section specific daily coefficients on import unit values (specification 2). The regression includes augmented HS-postal code-country triplets fixed-effects and a country specific trend. Errors are clustered at the postal code level.

### 4.7 Graphs for distance related regressions

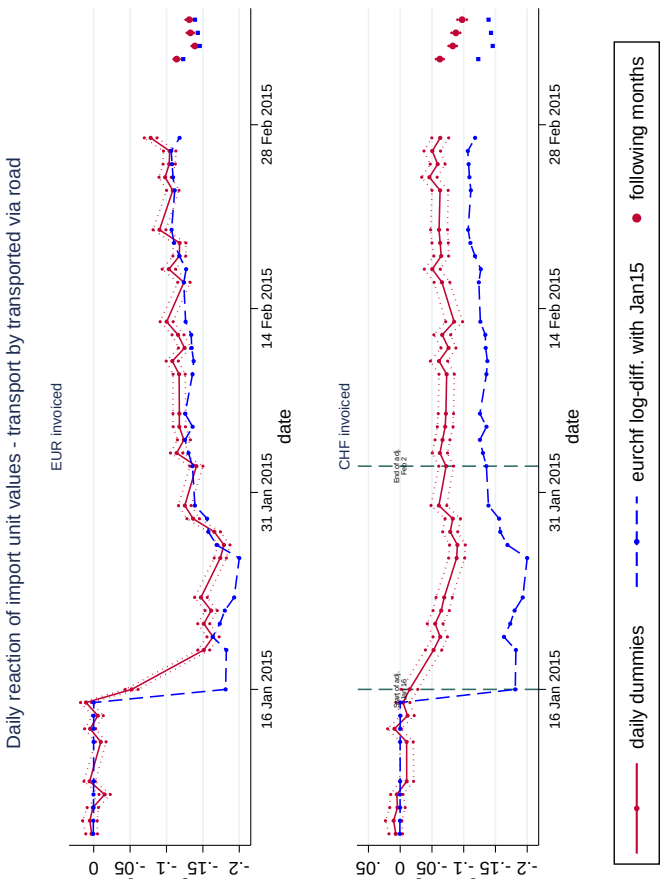
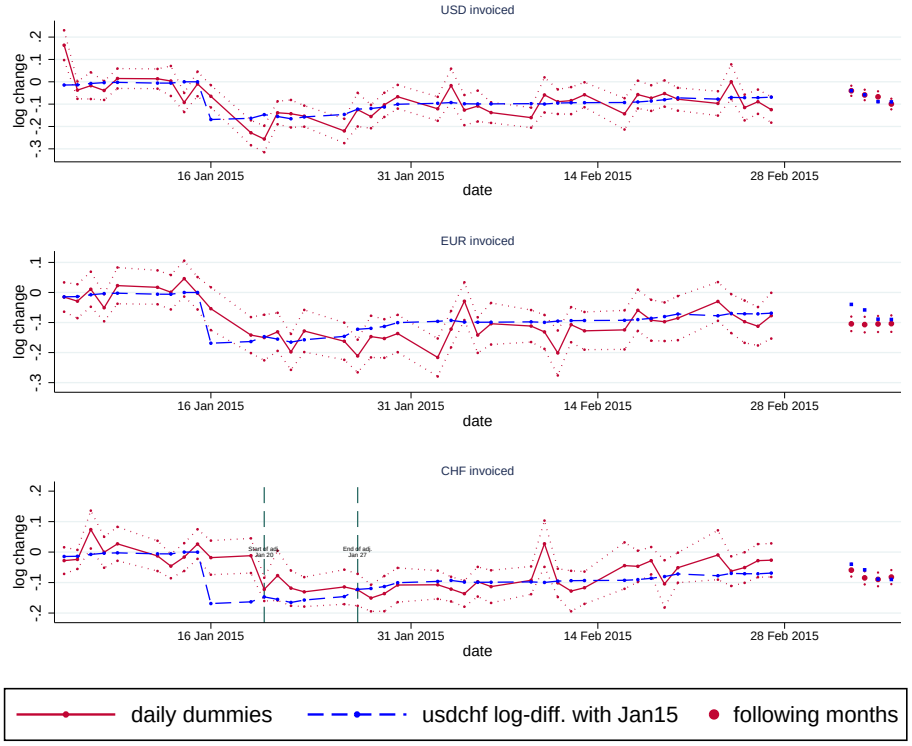



Figure 19: Daily dummies for import unit values (specification 2). The sample includes only imports transported via road. The regression includes augmented HS-postal code-country triplets fixed-effects and a 2-digit HS-country specific trend. Errors are clustered at the postal code level.

Figure 20: Daily reaction of import unit values - trade with the US




Daily dummies for import unit values (specification 2). The sample includes only imports from the USA to Switzerland. 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.

## Appendix 4: 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 $\hat{l} > 0$.[58]

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:

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

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[59], 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 $\rho$.

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).

[58] 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.

[59] 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 $\rho$ 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.