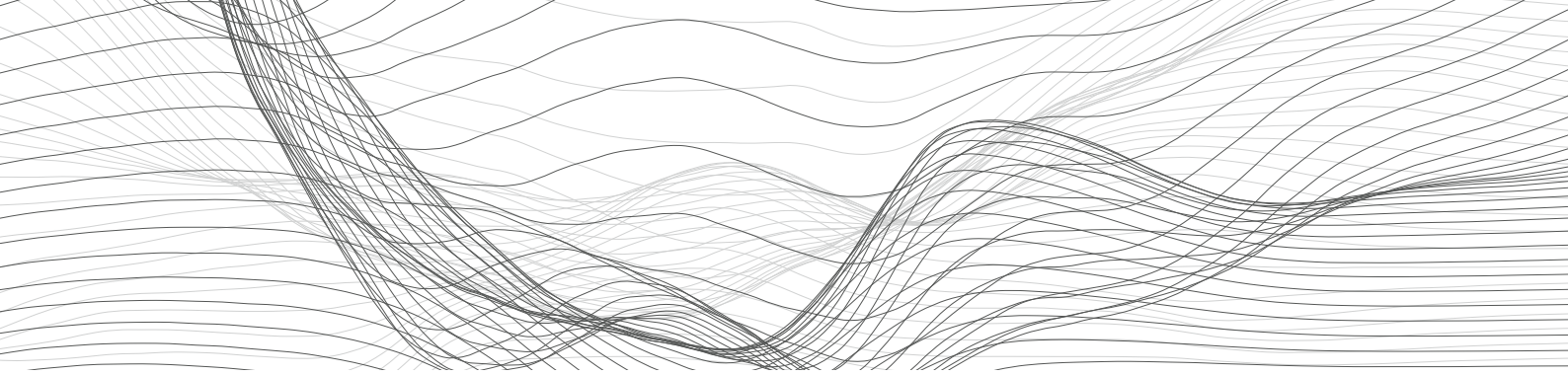

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SNB Working Papers
5/2018

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Legal Issues

ISSN 1660-7716 (printed version)
ISSN 1660-7724 (online version)

The Speed of Exchange Rate Pass-Through*

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January 6, 2018

Abstract

On January 15, 2015, the Swiss National Bank discountinued 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 pass-through of this unusually clean exchange rate shock into import unit values at the daily frequency using Swiss transaction-level trade data. Our key findings are twofold. First, for goods invoiced in euros, the pass-through is immediate and complete. Second, for goods invoiced in Swiss francs, the pass-through is partial and exceptionally fast, beginning on the second working day after the exchange rate shock and reaching the medium-run pass-through after twelve working days on average.

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

*The views expressed in this study are the authors' and do not necessarily reflect those of the Swiss National Bank. We would like to thank Philippe Bacchetta, David Berger, Tobias Cwik, Charles Engel, Fernando Giuliano, Gita Gopinath, Mathieu Grobéty, Carlos Lenz, Francesco Lippi, Rita Kobel, Barbara Rudolf, Juan Passadore, and Mathias Zurlinden for their valuable comments and Olga Mian for excellent research assistance. We are grateful to Hasan Demir for his invaluable help with the Swiss Customs Office data and Jean-Michel Zürcher for his support with import prices prepared by the Federal Statistical Office. All remaining errors are our own.

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1 Introduction

The exchange rate pass-through (ERPT) measures the rate at which prices of traded goods change in response to exchange rate changes. The ERPT plays a central role for the dynamics of border prices, determining key economic aggregates such as net exports or global imbalances. A dynamic literature studies the ERPT, with early work essentially regressing aggregate price changes on lagged exchange rate changes.[1] Improving data availability has led researchers to analyze micro prices, identifying transaction-level characteristics such as the invoicing currency as key determinants of the ERPT.[2]

Recent advancements notwithstanding, estimations of the ERPT typically struggle with the notoriously endogenous nature of the exchange rate. Not only does the sum of individual price changes – inflation – influence nominal exchange rates, but macroeconomic shocks are also likely to simultaneously impact a country's prices and its exchange rate.Stainless identifications of the causal impact of exchange rates on border prices remain elusive.

This paper exploits an unusually clean exchange rate shock to circumvent typical identification issues of ERPT estimates. The shock originates from the Swiss National Bank's (SNB) decision to discontinue the minimum exchange rate policy of one euro against 1.2 Swiss francs on January 15, 2015, which resulted in a sharp appreciation of the Swiss franc against the euro. Figure 1 illustrates the dynamics of the nominal bilateral exchange rate (solid line) and the monthly real exchange rate (dotted line) from 2011 to 2015. On January 15, 2015, the series shows a sharp and persistent appreciation.Apart from a temporary overshooting, the fluctuations before and after this shock are mild relative to the drop itself. The forward rates from January 14, 2015, (plus signs) indicate that the exchange rate shock was not anticipated by financial markets.

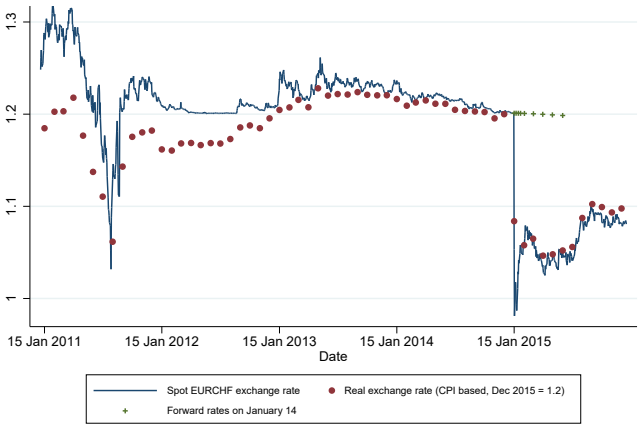
The sharp exchange rate shock is exceptional in several respects. It materializes in one day and occurs after a long period of stability.Further, it affected a historically stable currency and was not accompanied by macroeconomic turmoil, which is frequently the case in episodes of large exchange rate shocks (see, e.g., Burstein et al. (2005)).

The exceptionally clean nature of the exchange rate shock allows us to highlight one feature of the ERPT that is particularly difficult to identify:

[1] See Menon (1995) for an early literature survey.

[2] See, e.g. Gopinath et al. (2010) and Chung (2016).

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



Sources: SNB, Datastream

the speed of the ERPT. In this paper, we therefore analyse the pass-through of the exchange rate shock into unit values of Swiss import from the euro area at the daily frequency. A low number of days between the initial exchange rate shock, the first response of unit values and the completion of the medium-run ERPT indicates a high speed of the ERPT.

Our estimations, which we run separately for transactions invoiced in euros and in Swiss francs, yield two main results.First, for goods invoiced in euros, the ERPT is immediate and complete: the import unit values move one-to-one with the exchange rate after the exchange rate shock. Second, for goods invoiced in Swiss francs, the ERPT is partial and materialises extremely fast. Unit values begin to adjust on the second working day after the shock, and most of the medium-run ERPT is achieved after 12 working days. About two weeks after the shock, the transition period of the ERPT ends. The remarkably fast ERPT survives a large number of robustness checks, including regressions for subgroups of product classes and for Swiss export data.

We stress that we estimate the ERPT into unit values. Certainly, unit values are not prices and we cautiously assess the resulting limitations for the interpretations of our results. Having scrutinised these limitations – in particular possible substitution effects, selection effects, and potential misreporting – we nevertheless conclude that our findings do contain information about underlying price changes. The first of our results with daily data suggests that nominal euro prices remain unchanged so that unit values,

denominated in Swiss francs, react mechanically and instantaneously to the exchange rate shock. Our second finding suggests that the nominal prices of Swiss franc-invoiced imports do adjust and that, moreover, this adjustment is extremely fast. In other words, if a firm chooses to change its border price after the exchange rate shock, it does change its price promptly. Taken together, our two findings underscore that the invoicing currency is a central determinant of the ERPT.

Our work connects to various branches of the literature on the ERPT. Regarding the magnitude of the ERPT, our estimates are well in line with the typical findings, which vary between 0.4 and 1 for the majority of countries (a 10% appreciation in the exporter's exchange rate is associated with a rise in import prices by 4% to 10%).[3] Our findings also align with the recent literature that highlights the role of invoicing currencies for the ERPT (see, e.g, Bacchetta and Van Wincoop (2005), Engel (2006), and Goldberg and Tille (2008)). Specifically, Gopinath et al. (2010) suggest that the ERPT into U.S. import prices is complete for non-dollar-invoiced imports and is moderate for U.S. dollar-invoiced imports.[4] Consistent with that work, we show that the ERPT is complete for non-CHF invoiced imports, and partial for CHF invoiced imports.

Compared to existing estimates, our estimated speed of the ERPT is unusually fast. Existing work suggests that in normal times the 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." Analysing detailed transaction-level import prices, Gopinath et al. (2010) find that the pass-through requires approximately 18 months to be completed. Burstein and Jaimovich (2012), in turn, find quicker adjustments using Canadian and U.S. scanner data and show that retail prices adjust to exchange rate shocks within approximately 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 analysing the speed of ERPT into unit values of imported products at the daily frequency. Our finding of an exceptionally fast ERPT may be explained by the fact that we analyse a particularly large exchange rate shock. As recently pointed out by Alvarez et al. (2016) and

[3] Specifically, our estimates of ERPT between 1 (for euro-invoiced imports) and 0.6 (for Swiss francs invoiced imports) confirm previous estimates by Campa and Goldberg (2005), who report an ERPT for Switzerland of 0.9.

[4] At the same time, and much like important studies in the field (Gopinath et al. (2010) and Devereux et al. (2017)), our study is silent on the question of the choice of invoicing currency. Instead, we take the choice of invoicing currencies as given.

Alvarez et al. (2017), firms may optimally choose not to adjust prices to small shocks, whereas the need to adjust prices quickly may increase in the face of large shocks (see also Corsetti et al. (2008) and Gagnon (2009) for related studies on state-dependent adjustment).

A closely related branch of the literature assesses the ERPT in episodes of large exchange rate shocks. Burstein et al. (2005) document that import and export prices of tradable goods respond rapidly to large devaluations. Confirming this general statement, our study makes at least three important advancements. First, we analyze the reaction to an espe-cially clean exchange rate shock. Second, we refine the time-grid of the analysis and third, we disentangle price adjustments by groups of invoicing currencies. At the same time, our interpretation of fast nominal price ad-justments differs somewhat from influential studies. Thus, Gopinath and Rigobon (2008) document that adjustments of U.S. import prices from ori-gin countries with large devaluations were qualitatively "as expected, but [...] surprisingly weak."[5] Our estimates do not exhibit the surprising lack of reaction to changes in the exchange rate. We attribute the difference between our findings and those in Gopinath and Rigobon (2008) to the dif-ferent nature of the exchange rate shock: the mild reaction documented in the latter study may derive from the fact that the underlying devaluations were gradual and partly anticipated, so that anticipated prices adjustments possibly mitigated the price reactions on impact. Consistent with the view that these measurement issues are minimized in the episode analyzed in the current paper, our estimates suggest faster price adjustment. Other related studies consider the large Mexican devaluation in 1994 (Verhoogen (2008)) and of the Brazilian real (Flach (2016)) to establish causality in the ERPT estimates.[6] We contribute to this literature by analyzing the pass-through of an unusually clean, single-day exchange rate appreciation.

The literature on the ERPT has also identified firm- and product-specific determinants of the ERPT. Some contributions highlight the role of firm size (Berman et al. (2012)), the share of imported inputs (Amiti et al. (2014)), and product quality (Chen and Juvenal (2016) and Auer et al. (2014)). We contribute to this literature by assessing and confirming the role of market shares highlighted by Atkeson and Burstein (2008) and Auer and Schoenle

[5]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. Compare Figure II in Gopinath and Rigobon (2008).

[6]See also Cravino and Levchenko (2017) for a study of the real distributional effects of the peso's depreciation during Mexico's "Tequila Crisis".

(2016).

This paper is, to the best of our knowledge, the first to estimate the ERPT at the daily frequency. To some extent, this is unsurprising because ERPT estimations at the daily frequency only make sense in the rare case when the underlying shock is sharp enough so that the price reactions are identified with reasonable confidence. The large exchange rate shock after the SNB's policy decision is an example of such a rate event and thus perfectly suits the purpose of our study. The gains from working with an unusually detailed dataset containing the day and invoicing currency of transactions require us to compromise in other dimensions. The dataset 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 Harmonized System (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.

The remainder of the paper is organised as follows. Section 2 describes the exchange rate shock and its economic background. Section 3 describes our main data source, Section 4 reports our empirical results and Section 5 presents further robustness checks. Finally, Section 6 concludes.

2 The FX shock and its economic environment

To fully appreciate the contribution of the present study, it is important to recognise the unusually *clean* nature of the exchange rate shock we analyse. This section therefore describes the details of the shock and Switzer-land's macroeconomic conditions around January 2015. We document that the appreciation occurred in a stable macroeconomic environment and that the Swiss economy quickly settled to a new equilibrium after the shock. The full picture suggests that the Swiss franc appreciation was largely a nominal shock and that it was, moreover, exogenous to firms' pricing decisions.

2.1 The exchange rate floor: monetary policy background

The SNB pursued a policy of a minimum exchange rate (hereafter 'floor) of 1.2 Swiss francs against the euro from September 6, 2011 to January 15, 2015. This unconventional policy was introduced in response to appreciation pressures on the Swiss franc during summer 2011. These pressures were associated with safe haven flows into the domestic currency arising from

the Euro crisis. At the time, the SNB stated that "[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."[7] The SNB stated that it was fully committed to the policy.

Figure 1 plots the daily nominal bilateral euro-Swiss franc and the real monthly EURCHF exchange rate from 2011 to 2015. During the period of the floor, the Swiss franc hovered near the minimum rate. Over the entire period the real exchange rate closely tracks the nominal rate.

2.2 The discontinuation of the exchange rate policy and Swiss franc shock

The period of exchange rate stability ended abruptly with the announcement of the discontinuation of the floor at 10:30 (Zurich local time) on January 15, 2015. The timing of the SNB's announcement was motivated by the changing conditions of global financial markets. In particular, the increasing differences in monetary policy actions between the European Central Bank and the Federal Reserve prompted the SNB's decision. Referring to the preceding policy hikes in the United States, the SNB press release from January 15, 2015, stated that "[r]ecently, divergences between the monetary policies of the major currency areas have increased significantly [...] and "...concluded that enforcing and maintaining the minimum exchange rate for the Swiss franc against the euro is no longer justified."

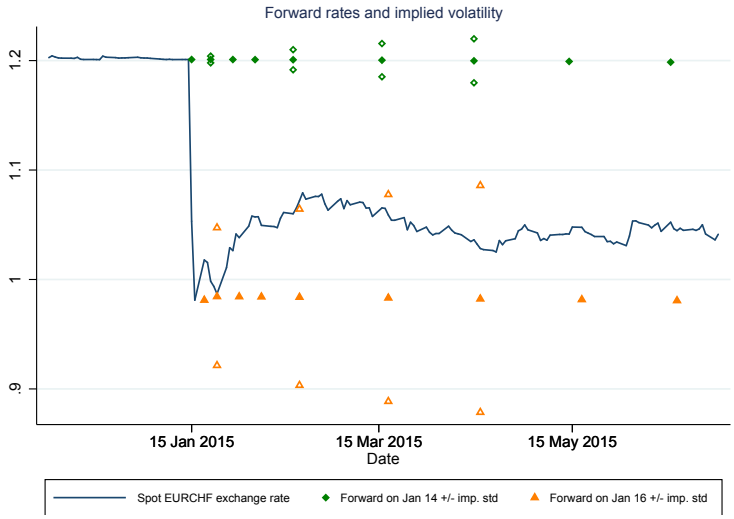
The SNB's decision to discontinue the floor took financial markets by storm.[8] The EURCHF rate fell from 1.2 to 0.88 in the first hours of trading after the announcement and closed at 0.99 for the day (17:00 Zurich local time). Figure 2 shows this steep drop was large and immediate. The EURCHF's rapid appreciation was also persistent. The Swiss franc had appreciated by 11% against the euro by the end of January. The daily rate stood slightly above 1.2 before the policy decision but 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 also unanticipated. Figure 2 plots the forward rates from January 14, 2015, i.e., one day before the SNB's announcement which remained at the minimum rate of 1.2. The small implied standard deviations of the January

[7] See SNB press release from September 6, 2011.

[8] Market commentary regarding the SNB's decision on January 15, 2015, is extensive. One of numerous examples is from Reuters, see http://www.reuters.com/article/us-swiss-snb-cap-idUSKBN0KO0XK20150116.

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



Sources: SNB, Datastream, own calculations.

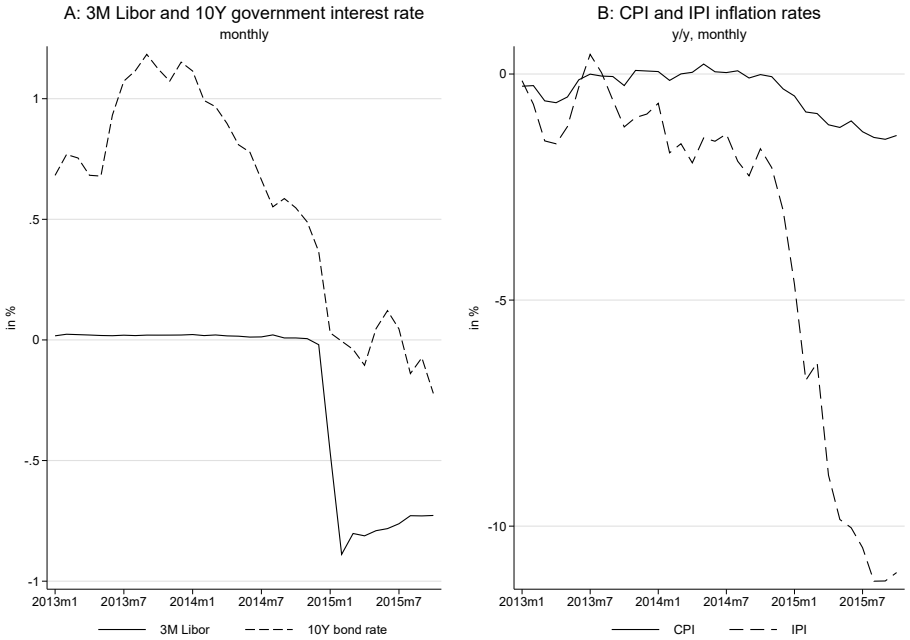
14 forward rates, included in the figure whenever available, indicate little uncertainty. The figure also shows that forward rates dropped to 0.98 on January 16, 2015, the day after the announcement (triangles).[9] Overall, the permanent shock to the Swiss franc on January 15, 2015 was large, abrupt, and unanticipated.

2.3 The Swiss macroeconomy around the exchange rate shock

The Swiss economy was stable before the exchange rate shock and proved remarkably resilient in its aftermath. The SNB's press release on January 15, 2015 which announced the discontinuation of the exchange rate floor also announced the lowering of its policy rate by 0.5% to the range− 1.25% to − 0.25%.The SNB stated that the interest rate cut sought "to ensure that the discontinuation of the minimum exchange rate does not lead to an inappropriate tightening of monetary conditions." Figure 3 Panel A illustrates that the Libor (solid line) dropped instantaneously to the middle of the SNB's new target range. The negative interest rate policy had a pronounced effect on the 10-year government interest rate (dashed line),

[9]Figures 9 and 10 in section B of the Online Appendix show that the forward rates at later dates reveal that the appreciation was permanent.

Figure 3: Prices – 2013 to 2016



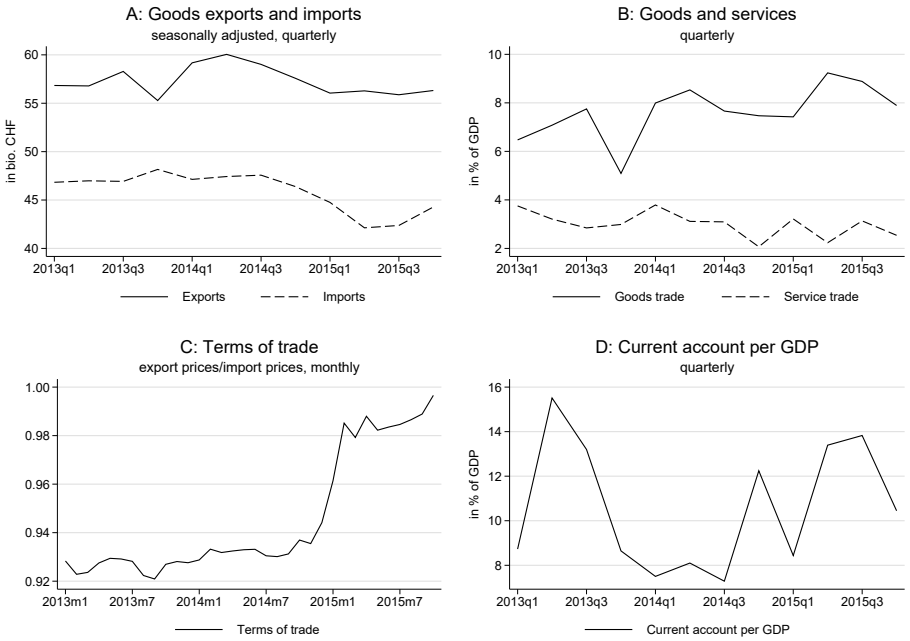
Sources: SNB, Datastream, own calculations.

which also moved into negative territory.

The nominal exchange rate shock translated into a drop in Swiss import prices and CPI within the first six months of 2015. Figure 3 Panel B plots year-to-year changes of the Swiss import price index (in CHF, dashed line) and Swiss CPI index (solid line). The Swiss import price index dropped sharply to over -10% after six months of the exchange rate shock. Swiss CPI inflation fell from just under 0% in December 2014 to its trough of -1.48% in August 2015. Thereafter, inflation returned close to its pre-shock levels in January 2016.

Notwithstanding changes of nominal variables, Switzerland's exter-nal balances and real domestic economy absorbed the exchange rate shock remarkably well. Figure 4 plots four indicators of external balances between 2013 and 2016. Panel A shows that nominal exports and imports (quarterly, seasonally adjusted in CHF) exhibited a mild responses onlz. Imports and exports continued a mild decline that began prior to the exchange rate shock but recovered after mid 2015. Panel B shows the (quarterly) trade

Figure 4: External Balances – 2013 to 2016



Sources: SNB, Datastream, own calculations.

balance of goods (excluding non monetary gold) and services as a share of GDP. The surpluses of the trade balances averaged 8% in goods and 3% in services over the sample. Both trade balances are remarkably stable around Januarz 2015. Panel C plots the monthly terms of trade (export over import prices). The plot shows the expected response to the exchange rate shock. Switzerland gained roughly 5% in purchasing power on international markets. A striking feature of Swiss terms of trade is that it is extremely stable in the months prior and after the exchange rate appreciation. Last, Panel D shows that the Swiss current account surplus is large and subject to extreme fluctuations. However, the graph does not indicate that the large exchange rate appreciation generated an exceptional response in the Swiss current account.

Finally, Figure 5 plots four indicators of real economic activity around the time of the shock. The indicators show that Switzerland's real economy absorbed the exchange rate shock remarkably well. Panel A shows the year-on-year change in log GDP at the quarterly frequency. GDP growth fell

sharply in Q1:2015 to -2.0%. This single quarter contraction was an abrupt change to economic growth, which averaged above 2% in 2013 and 2014. After the short contraction, however, Swiss real growth GDP rates recovered and resumed to their prior levels close to 2%.

Figure 5 also shows that investment growth, consumption growth, and unemployment did not register unusual behavior at and around the time of the exchange rate shock. Real annual investment growth (i.e., capital formation, Panel B) shows no response to the exchange rate shock, despite otherwise large fluctuations. Similarly, real annual growth of consumption per capita (Panel C) experienced no break in stability. Last, neither the internationally consistent ILO rate of unemployment nor the Swiss-specific measure of unemployment show a strong response (Panel D). Both measures rise only slightly after the exchange rate shock and their movements are well within the usual fluctuations prior to the SNB's policy change.

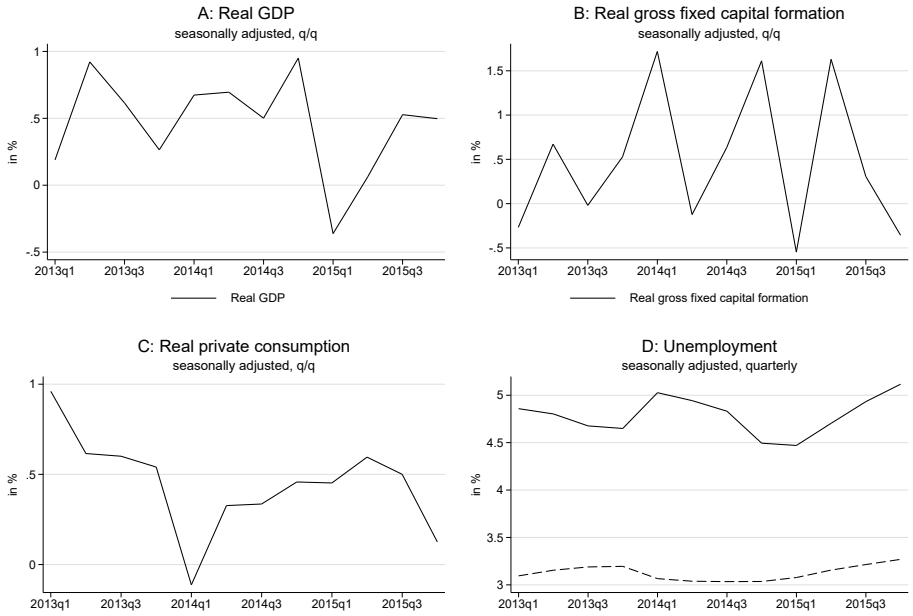
Overall, the response of Switzerland's real economy to the large and sudden exchange rate appreciation offers a relatively tranquil picture: investment, employment, and household consumption remained stable, while output experienced only a temporary drop.[10] The improvement in the terms of trade did not lead to a collapse in exports nor a surge in demand for imports.

Overall, three observations stand out as particularly important for the purpose of our study. First, the SNB's policy decision to abandon the exchange rate floor was based on external policy factors. This implies that the exchange rate shock was independent of firms' pricing decisions or domestic demand factors. Second, the exchange rate shock occurred after a time of exceptionally low exchange rate volatility and a stable macroeconomic environment. Third, the real side of Switzerland's economy proved surprisingly resilient in response to the exchange rate. This third observation addresses the possible concern that the nominal shock was accompanied by a structural break in Switzerland's domestic economy, which could otherwise induce an omitted variables bias in our estimates.[11]

[10]The explanations for the temporary contraction in real activity for Q1: 2015 depend on how GDP is measured. Under the production approach as shown in Figure 5, the main negative component is in statistical residuals and inventory. Instead under the expenditure approach, it is a sharp fall in new equipment investments.

[11]Episodes of large exchange rate devaluations analyzed in other studies often fall in crisis episodes with large losses in GDP. See, e.g., Alessandria et al. (2015), Cravino and Levchenko (2017), Flach (2016), and Verhoogen (2008).

Figure 5: Real economy – 2013 to 2016



Sources: SNB, Datastream, own calculations.

3 Data description

Our empirical estimates of the speed of ERPT rely first on a large and exogenous exchange rate shock and second on detailed transaction-level trade data at the daily frequency for separate invoicing currencies. This section discusses the key features of our trade data. Additional details on the trade data can be found in Section C of the Online Appendix.

The Swiss Customs Administration or Eidgenössische Zollverwaltung (EZV), records all Swiss customs transactions.[12] The data include information on the (c.i.f.) value in Swiss francs, quantity (mass or units), product category, partner country, transaction date, Swiss postal code, invoicing currency, and transportation mode. 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. [13] The

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

[13]Small transactions with a simplified custom declaration procedure are not included in

unit of observation is one transaction. We restrict the data to transactions with the euro area, which accounts for 64.6 percent of all imports for the period between January 2014 and June 2015.[14]

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 approximately 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.[15]

Each observation contains an 8-digit Harmonised System product classification (HS) number and 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 shipment expressed in kilo. Approximately 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. We construct unit values by dividing the value of the transaction by the supplementary unit when available and by mass when unavailable.

Our dataset contains two additional variables that are crucial for the empirical exercise.[16] First, the transaction date, which reports the day when the goods physically cross the border. Second, the currency in which transactions are invoiced. For each customs declaration, the invoicing currency is recorded as one of the following five categories: CHF, EUR, USD, other EU currencies and other non-EU currencies.

An important observation concerns the conversion of transactions that are not invoiced in Swiss francs. For imports, the value of such transactions

our dataset. Eligible goods have a value of less than CHF 1000, a weight of less than 1000 kg, and are noncommercial transactions or cultural goods. According to SNB aggregate statistics, these totalled 10.184 billion in imports (or 5.7% of the imports covered in our analysis) for 2014. Notably, our dataset also includes small transactions that were not declared through a simplified procedure.

[14] In a robustness check in Section 4.7, we also investigate results regarding imports from the United States, which account for 6.5 percent of all imports for the period between January 2014 and June 2015.

[15] Although the difference in the share of invoicing in euros, Swiss francs, and other currency for the pre- and post-shock is statistically significant, the magnitude of the change is small. In the Online Appendix, Figure 13 also informally shows that there is no noticeable systematic switching between invoicing currencies.

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

Table 1: Summary statistics

	Total sample	Pre-shock	Post-shock
Imports (euro area to Switzerland)			
Based on transactions			
Average unit value (log)	3.382	3.417	3.309
	(2.035)	(2.033)	(2.039)
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	0.660	0.655	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	29193662	19762575	9431087
Average number of daily transactions	53468.25	52006.78	56813.78
	(33554.09)	(32601.80)	(35513.79)
Average EZV EURCHF exchange rate	1.176	1.226	1.057
	(0.079)	(0.009)	(0.018)

Note: standard deviations are shown in parentheses. The total sample spans from January 1, 2014 to June 30, 2015. The pre-shock period extends from January 1, 2014 to January 15, 2015, whereas the post-shock period is from January 16, 2015 to June 30, 2015.

is converted into Swiss francs using a specific exchange rate that is published daily by the EZV and 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., 4:30 a.m. for December 14, 2015). On January 15, 2015, in particular, the exchange rate was published before the SNB's announcement: its value for January 15, 2015 (applicable to the January 16, 2015, transactions) was 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. For exports, the same rule applies in principle. However, a monthly average exchange

rate can also be used.[17] The uncertainty as to which exchange rate was used motivates our focus on import transactions. Unfortunately, several transactions can be declared under a single custom declaration but the currency of invoicing is reported at the declaration level. Hence transactions invoiced in different currencies may be classified under a single currency. In these occurrences, the currency covering the majority of the declaration's value is entered and our dataset attributes this currency to all transactions.

For additional details on the data – and especially for exercises addressing possible concerns about systematic selection into euro- and Swiss franc sample – the reader is referred to Section C of the Online Appendix.

4 Estimation strategy and results

This section describes our strategy to estimate the reaction of unit values within a short period around January 15, 2015 and then presents and discusses our findings.

4.1 Estimation of short-run reactions

Our estimations are based on daily data to track the reaction of unit values to the shock on a very precise time-grid. To capture the reaction to the large shock, we estimate an equation with daily dummies immediately before and after January 15, 2015. Specifically, we use the sample of all import transaction between January 2014 and June 2015 and perform an event-study analysis based on the following specification.

$$\ln(p_k) = \alpha_{i_k j_k s_k} + \sum_{d=-8}^{31} \beta_d^D D_k^d + \sum_{m=2}^{5} \beta_m^M M_k^m + X_k\gamma + \varepsilon_k. \qquad (1)$$

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 working day of 2015 (Monday, 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 coefficients on the daily dummies around January 15 track the average daily

[17] 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 $m-1$. "International groups" can also use their internal accounting exchange rate if they are registered with the EZV

level of the unit values around the shock on a very fine time grid. M_k^m are monthly dummies from March 2015 to June 2015, taking a value of 1 if the transaction k occurs 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 occur on Fridays.[18]

The specification laid out in model (1) 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 in a fine resolution of the time dimension. Specifically, the use of daily dummies ensures that only changes in unit values on a specific day are captured, which can then be related to the corresponding exchange rate movements. As indicated in section 2, the absence of significant exchange rate changes before the shock ensures that lagged effects of prior exchange rate movement do not contaminate our estimation of the coefficients on the daily dummies. Other price determinants such as marginal costs are also unlikely to change within days immediately after the shock.[19] [20]

4.2 Estimation results

For expositional purposes, Figure 6 summarises the estimates of equation (1) in graphical form. The figure plots the estimated coefficients on the daily and the monthly dummies by invoicing currency, together with their 95% confidence intervals and along with the cumulative change in the exchange rate since January 15^{th} (blue dashed line). All estimates are rescaled by the average of the pre-shock dummies coefficient, so that the values on the vertical axis can be interpreted as the cumulative change of unit values since the shock.[21]

The top panel of the figure, which corresponds to the EUR-invoiced

[18] 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).

[19] We cannot exclude the possibility that exchange rate movements after the shock are influencing unit values in periods further away from the shock; thus, the value of monthly dummies for March to June provides only an imprecise estimate of the effect of the January 15 shock. One substantial shock to the EURCHF exchange rate occurs after June 2015, which is excluded from our sample.

[20] The downside of this specification is that it is less readily comparable with standard specifications as in Gopinath et al. (2010), which include exchange rate lags to up to two years. We therefore also provide alternative estimates based on monthly regressions in the Online Appendix F.

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

imports documents an immediate effect of the exchange rate shock on unit values. The daily dummies closely follow the exchange rate, indicating a complete pass-through in the period covered by daily and monthly dummies. One exception seems to occur on the first day after the shock (January 16^{th}). This exception is explained by the fact that the exchange rate by which euro-invoiced imports are officially converted into Swiss francs refers to the previous day's opening course and thus corresponds to the pre-shock period.[22] Had the correct exchange rate been applied for the conversion, estimated coefficients of the daily dummies would almost perfectly track the exchange rate.

The bottom panel of Figure 6 corresponds to imports invoiced in Swiss francs. Unsurprisingly, the response of unit values is not one-to-one with the exchange rate in this sample. Strikingly, however, the error bands indicate that there is a non-trivial, statistically significant response of unit values shortly after the exchange rate shock already: the point estimates of the coefficients on the daily dummies are significantly different from the pre-shock level starting on the second working day after the shock. Indeed, within two working days after the shock, unit values drop as much as a fraction of 0.32 of the exchange rate change. After a total of twelve working days the pass-through is already 90% of the average pass-through of the last four months of the sample. In other words, the partial pass-through materialises exceptionally fast. Compared to the typically slow ERPT found in the literature, this finding is remarkable and unexpected.

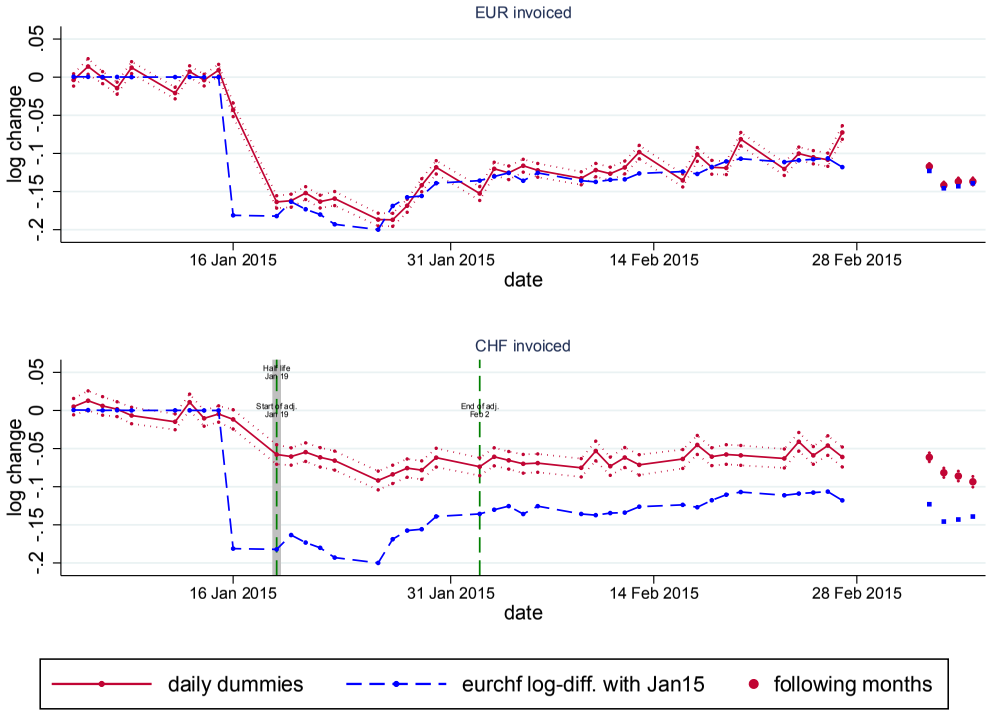
In the bottom panel of the figure, we also provide formal measures of the beginning and end adjustment of the pass-through. These are indicated by vertical dashed lines.[23] The beginning of the adjustment is defined as the first day for which the cumulative change in unit values (the estimated β_d^D in (1)) is statistically different from the average of the pre-shock daily dummies. The end day is defined as the first day the accumulated pass-through reaches 90% of the medium-run pass-through ratio, which is defined as the average of the four monthly pass-through ratios. We also provided confidence intervals for these statistics in Table 3 in Section 5 below.[24] The figure also includes

[22] For more details, see the data description in Section 3.

[23] We stress that we take our estimates of start and end day as indications, not as hard, literal boundaries of the adjustment period. See also Section A7 of the Online Appendix for a further discussion of potential biases of the *start* and *end* day.

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

Figure 6: Daily reaction of import unit values



Daily dummies for import unit values (specification 1). The regression includes augmented HS-postal code-country triplet fixed-effects and a 2-digit HS-country specific trend. Errors are clustered at the postal code level. The sample spans from January 1, 2014 to June 30, 2015.

a measure of the *half-life* of the pass-through, defined as the time elapsed until half of the pass-through has materialized (grey vertical bar).[25]

Overall, the *start* and *end* day in Figure 6 indicate that the unit values in the CHF-sample did react to the exchange rate shock and quickly so. The pass-through in this sample was *fast* in the sense that both, the start and end day, lie within a short period after the shock. Within two working days after the shock, unit values drop significantly and after 12 working days, 90% of the medium-run pass-through is completed.

Together, our estimations summarised in Figure 6 show that the pass-through of the exchange rate shock in the EUR sample was complete and immediate, while in the CHF sample it was partial and fast.

4.3 The mirror image: export transactions

The primary goal of our paper is to assess the speed of ERPT into Swiss import prices. Nevertheless, this section offers a quick look at the complementary side of Swiss trade, analysing the ERPT into Swiss export prices. We treat the analysis of export transactions as a side issue because of mild but consequential differences in reporting procedure. As described at length in the data section, the value of euro-invoiced transactions are converted into Swiss francs by a daily exchange rate administered by Swiss customs. Unlike for import transactions, however, exporting firms have the option to convert values through a monthly average exchange rate or an 'international groups' internal accounting exchange rate.[26] The monthly average applicable to a transaction in month, m, is the average of the daily exchange rate observed between the 25^{th} of the month $m-2$ and the 24^{th} of the month $m-1$. Our data do not track which exchange rate is used, thus impeding a clean assessment of the daily ERPT for the euro-invoiced sample. For that reason, we put less weight on the findings in the context of our paper's focus on the speed of the ERPT. In the second part of this section, we use the

$PT_{d_{start}} = 0$ is rejected and $PT_i = 0$ is not rejected for all $0 < i < d_{start}$. d_{end} is such that $PT_{d_{end}} \geq 0.9\frac{1}{4}\sum_m PT_m$ where m covers all months after the daily dummies, namely March to June 2015. To construct confidence intervals, we bootstrap these statistics and report their median on the figure, and a 95% bootstrap confidence interval in the tables, based on the 2.5^{th} and 97.5^{th} percentiles. For the bootstrap, we use our estimates of daily dummies and their covariance to draw from a multivariate normal distribution and compute the day statistics at each draw.

[25] When the medium-run pass-through is either 0 or one, as in the sample of EUR-invoiced imports, we do not define start-date, end-date or half-life of the pass-through.

[26] The latter option requires an according arrangement and registration of the firm with the EZV.

medium-run horizon of our export data to assess recent theories that relate the magnitude of the ERPT to market shares.[27]

Figure 7 plots our estimation results for euro-invoiced (top panel) and Swiss franc-invoiced (bottom panel) export transactions, corresponding to Figure 6 for imports. The figure shows that the pass-through of euro-invoiced exports is partial between January 15 and January 31 2015. This result is consistent with the view that euro prices remained unchanged and a fraction of the sample s is converted with a daily exchange rate (for this fraction the pass-through would be complete), while a fraction $1 - s$ of the sample is converted with a pre-shock exchange rate (for this fraction the pass-through would be zero).[28] After January, the daily dummies are much closer to the exchange rate, which is again consistent with the use of an updated monthly rate of January for February transactions.

The issue of different exchange rates used to convert shipment values does not arise for exports invoiced in Swiss francs. These results are thus easier to interpret. As in the case of import transactions, Figure 7 illustrates a significant and fast drop in export unit values of 0.38, with most of it being achieved after 11 days. (see also last row of Table 3 reporting the start/end day and medium-run pass-through estimates for exports). While the daily dummies are estimated less precisely than in the case of import transactions, they show that following the large nominal exchange rate shock, a non-trivial pass-through materialises remarkably quickly.

Overall, the assessment of export transactions illustrates two important points. First, to the extent that the ERPT is partial (as in the two CHF-invoiced subsamples for imports and exports), it does materialise surprisingly quickly. Second, the remarkably clean identification of the daily ERPT in the sample of Swiss imports crucially hinges not only on data availability but also on unique reporting conventions.[29] We will return to the comparison between the estimates based on import and export transactions, when discussing potential biases and drawbacks of the estimations in section 4.5 below.

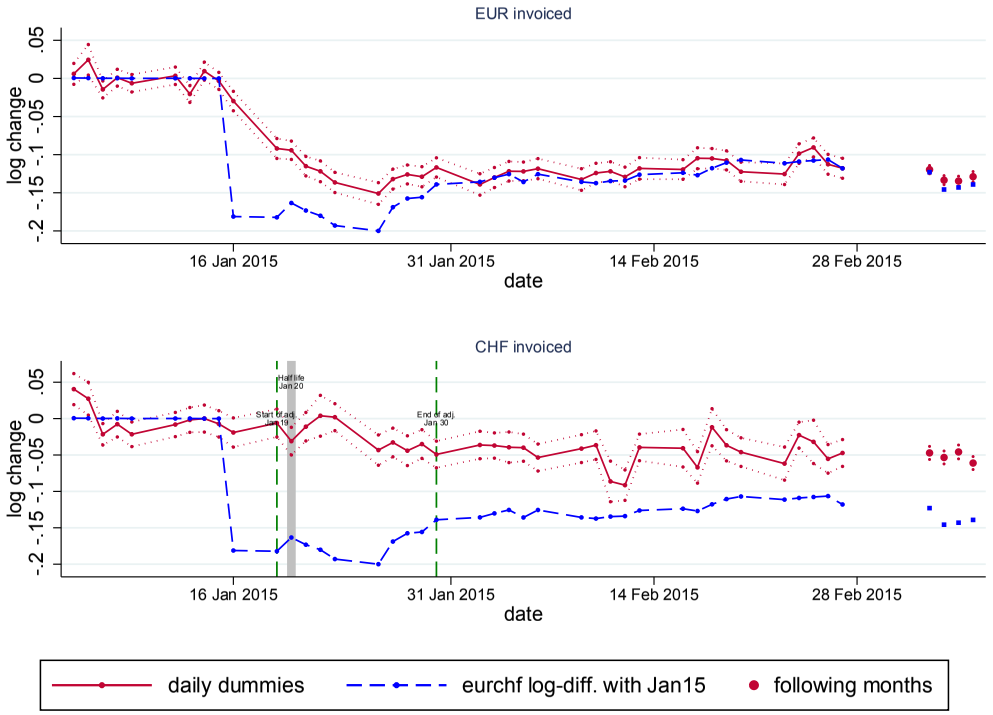
Having corroborated the main insights from the import sample with the sample of export data, we go one step further and use the export sample to assess theories relating the ERPT to market shares and market power. In

[27] Descriptive statistics related to exports can be found in table 7 in Online Appendix, Section A.3.

[28] The mix of different exchange rates thus seems to prevent the emergence of an immediate pass-through even on the daily time grid, which can be reasonably expected under the paradigm of strong price rigidities.

[29] Compare, in particular, the top panels of Figures (6) and (7).

Figure 7: Daily reaction of export unit values



Daily dummies for export unit values (specification 1). The regression includes augmented HS-postal code-country triplet fixed-effects and a 2-digit HS-country specific trend. Errors are clustered at the postal code level. The sample spans from January 1, 2014 to June 30, 2015.

particular, Feenstra et al. (1996) provide early evidence that the magnitude of the ERPT is hump-shaped in country-specific market shares. Auer and Schoenle (2016) recently define a model from Atkeson and Burstein (2008) to show that this result derives from a hump-shaped ERPT at the country and the firm level, combined with a complementary response to competitors' price changes. In the spirit of these studies, we define the Swiss market shares across European destinations (at the 6/digit HS level, using EUROSTAT data) and interact these market shares and their squared values with a dummy for transactions taking place after the shock to assess whether the response of unit values to the Swiss franc shock is indeed hump-shaped.[30]

Table 2 presents the results of the regression, where the coefficient on the dummy has been normalized by the change in exchange rate average before and after the shock to be interpreted as a pass-through coefficient. Consistent with our baseline regressions, we find almost complete pass-through and no significant effect of market shares for euro-invoiced transactions (Columns III and IV). Euro-invoiced prices simply do not seem to exhibit nominal price reactions. For Swiss franc-invoiced transactions, we find some evidence of hump-shaped relation between pass-through into export unit value and market share, both when the market share is defined at the country level (Columns I and II) or for the euro area. Using country specific market shares, when the market share is 0, the estimated ERPT is about 0.33. The pass-through initially decreases with market share until a rate of 0.1 at a market share of 0.24, at which point the rate increases in market share.

Table 2: Market share regressions

	(I)	(II)	(III)	(IV)	(V)	(VI)
	CHF	CHF	EUR	EUR	Pooled	Pooled
Market share:	country	euro area	country	euro area	country	euro area
Shock	0.33***	0.36***	0.85***	0.87***	0.66***	0.69***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Shock x ms	-1.95***	-3.81***	-0.07	-0.98	-0.31	-1.96***
	(0.72)	(0.88)	(0.47)	(0.75)	(0.42)	0.67
Shock x ms^2	4.05**	8.62***	-0.76	1.50	-0.03	3.54**
	1.79	(2.15)	(1.39)	(2.07)	(1.12)	(1.63)

Standard errors in parenthesis, clustered at the postal code level
All regressions include triplet fixed effects and good.country specific trends.

[30]We point out that this exercise necessarily relies on Swiss exports data, since Swiss imports from all destinations experienced a simultaneous shock of virtually identical size on January 15, 2015, implying zero variation in market shares of affected exporters. It would thus be impossible to distinguish the response to the shock to own supply cost from the complementary effect of competitors-price changes investigated in Auer and Schoenle (2016).

Our results thus confirm the earlier findings in Feenstra et al. (1996), Atkeson and Burstein (2008) and Auer and Schoenle (2016) using the single, sharp, and clean exchange rate shock from 15 January 2015.

4.4 Interpretation

Having established our estimation results, we are ready to state three main conclusions. First, the invoicing currency is a key determinant of the ERPT, as a comparison of the top and the bottom panel of Figures 6 and 7 clearly show. This statement holds both in the short (few days) and in the longer run (six month). With this broad and strong pattern, our analysis clearly confirms recent work like Gopinath et al. (2010)

Second, our documentation of a complete and immediate ERPT in the euro sample is consistent with the hypothesis that nominal prices do not change. Restricted to the short run, this observation fits the image that emerges from the classical literature on the ERPT: nominal border prices are slow to react and the ERPT fully materialize only after a number of months or years (see, e.g., Campa and Goldberg (2005)). Applied to the full horizon, the observation further suggests that prices, expressed in their invoicing currency, barely change even in the long run. Our estimates thereby confirm the findings of the recent contributions by Gopinath (2015) who shows that the assumption of entirely inflexible nominal border prices yields very good approximations of the ERPT in the longer run.

Third, our finding of a rapid partial ERPT in the sample with Swiss franc invoicing suggests that the frequency of nominal price adjustment after the exchange rate shock was high. We realise that it may appear as a leap of faith to judge nominal price adjustments based on unit values.Nevertheless, we claim that it is possible to establish a lower bound on share of prices that were adjusted in the days after the exchange rate shock. This claim is made under two relatively mild assumptions. First, substitution effects within the HS categories (e.g., from high to low quality products) were negligible in the days after the exchange rate shock.[31] Second, conditional on price adjustment, the size of the adjustment does not exceed the size of the exchange rate change.[32] Under these assumptions, the estimated pass-

[31]The sceptic regarding substitution effects is referred to the next section, where we discuss possible concerns in detail.

[32]Virtually all micro-data studies show that conditional price adjustments are less than unity. See Auer et al. (2017) for according estimations with Swiss consumer prices at the time of the exchange rate shock. Notice also that the lower the conditional pass-through, the higher is the implied frequency of price adjustment.

through of 0.32 (0.5) after two (eight) working days in the Swiss franc sample implies that at least 32% (50%) of the underlying nominal prices did change over these short periods.[33]

Overall, we read our findings of the sample with Swiss franc invoicing as suggestive evidence that a large fraction of underlying nominal prices changed quickly. Clearly, our finding contradicts the narrative that nominal prices are fixed in the short run. Indeed, a rough calculation based on the pass-though of 0.32 after two days suggests that the implied share of nominal price adjustments would be roughly 0.98 when applied to the monthly scale and 1 after one quarter.[34] For comparison, Gopinath and Rigobon (2008) report that half of nominal prices are unchanged after 10.6 (12.8) months for U.S. imports (exports).[35]

We view the estimations of the Swiss franc sample as the most striking, interesting, and important part of our results. They suggest that the frequency of price adjustments varies over time and may, in particular, be impacted by exogenous events like the large exchange rate shock. This view is in line with evidence of time variation of the frequency of price adjustment like in Gagnon (2009).[36]

Our interpretation of fast nominal price adjustments, in turn, implies that nominal rigidities played a minor role in the period immediately following the exchange rate shock. Our findings are thus consistent with state-dependent pricing frameworks as those of Dotsey et al. (1999) and Golosov and Lucas (2007) and less in line with time-dependent pricing models à la Calvo.[37] Our findings lie nearer to the recent work by Alvarez et al. (2016) and Alvarez et al. (2017), who show that the ERPT materializes faster in

[33]We discuss possible concerns and objections to this interpretation in detail in the following section.

[34]After 2 days the fraction (1-0.32) is unadjusted so the fraction $(1-0.32)^{20/2} = 0.02$ is unadjusted after a month with 20 working days or $(1-0.32)^{3*20/2} = 0.00$ after a quarter with 3 months.

[35]Kaufmann (2009) reports that 13.8% of prices in the Swiss CPI basket are adjusted within a quarter between 2000 and 2005, implying a median duration between price changes of 4.6 quarters. Bils and Klenow (2004) reports the much lower value of 4.3 months medium duration for U.S. prices. Lein (2010) reports survey data of Swiss firms, that between 1999 and 2007, only 34% of firms surveyed have changed their prices in the previous quarter.

[36]See Auer et al. (2017) and Kaufmann and Renkin (2017) for evidence based on Swiss data.

[37]We also observe that our findings are difficult to explain by pricing models based on *sticky information* à la Mankiw and Reis (2002). In particular, if a constant fraction of agents updates information and pricing plans within each period, the implied price adjustments cannot simultaneously match the frequency of price adjustments in normal

response to large exchange rate shocks than to small shocks. They further 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.

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."[38] The difference between our findings and the mild reaction documented in earlier studies may be explained by the fact that the exchange rate shock was unanticipated, whereas the devaluations based on earlier work were partly anticipated, so that prices could be adjusted in advance.[39]

Finally, we acknowledge that our interpretation of Figure 6 as evidence for fast nominal price changes may be challenged. Having neglected some important concerns to our interpretation of the results, we offer a thorough discussion of what we deem the most relevant of these concerns in the next section.

4.5 Possible concerns

This section discusses possible concerns to our interpretation of Figure 6 as evidence of nominal price adjustment. These concerns relate to three broad points. First, the relation of unit values and prices, second, the possibility of misclassification of invoicing currency and, third, the nature of our transaction-level data. We will discuss these three points in turn.

4.5.1 Unit values

Unit values are not prices. This obvious fact forces us to be very cautious when inferring unobserved price adjustments from observed changes of unit values. Two main factors warrant attention: potential shifts in the composition within each product classifications and product exit from and entry.

times and the large fraction of price adjustments suggested by our estimates. 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.

[38]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.

[39]Compare Figure II in Gopinath and Rigobon (2008).

Shifts in the composition of product categories constitute a funda-mental problem when relating prices and unit values. Problems arise as the mix of qualities within product categories may change, affecting unit values in a systematic way. We argue, however, that such systematic compositional shifts are unlikely to drive our results. In fact, the exchange rate shock resulted in an increase in the purchasing power of Swiss residents, so that they should be expected to substitute towards *higher* quality imports. This effect, however, would induce an *increase* in import unit values, while Figure 6 documents a decrease. Thus, quality substitution should attenuate the estimated decrease in the unit values of Swiss imports rather than driving it. We further observe that the unit values *in euros* of euro-invoiced imports remained very stable (top panel of Figure 6). This observation indicates that strong substitution effects are not affecting this set of transactions. In the absence of a systematic link between the invoicing currency and the proclivity for substitution, there is little reason to suggest that substitution effects are prevalent in the sample of Swiss franc-invoiced imports. Finally, parallel observations for the export sample confirm these observations.[40]

Another concern related to substitution and compositional shifts of the sample arises from the potential exit and entry of firms or products from the sample. In particular, Gagnon et al. (2014) suggest that exit into and entry from export markets induces an attenuation bias in the pass-through estimations. In the presence of such a bias, however, the true pass-through would in fact be larger than our estimated changes in unit values for Swiss franc-invoiced goods.[41] Nevertheless, in the Online Appendix we gauge the rate of exit and entry rate around the date of the exchange rate shock by examining the entry and exit of pairs of products and partner countries.[42] These measures do not reveal unusual entry dynamics around the date of the shock, both in terms of levels or relative to the previous year (see Figure 14 and the corresponding description in the Online Appendix).

In sum, the effect of the most relevant compositional shifts on the observed unit values seem moderate in the period of our analysis.

[40] See also Section 5.1 for further evidence that substitution effects are likely small.

[41] Gagnon et al. (2014) also report that empirically the 'biases are modest over typical forecast horizons' and even less so for our short period of two weeks.

[42] This measure captures only a subset of exits and entries. Indeed, any exit (entry) of a pair must reflect at least one product exit (entry) from the market in question, although the reverse is not true.

4.5.2 Misclassified invoicing currencies

Another concern may arise due to firms' potential misclassification of their invoicing currencies. Such reporting errors could indeed jeopardize our interpretation of the key findings. For example, suppose half of the import transactions recorded as Swiss franc-invoiced were actually priced in euros but converted to a Swiss franc invoice. In combination with *no* nominal price adjustment, that could generate the overall patterns of the bottom panel in Figure 6: zero pass-through of half of the sample (correctly recorded as CHF invoiced) and full mechanical pass-through of the other half (actually priced in euro) would mechanically average to the observed average pass-through rate of about 0.5.

We view the possibility that misclassification is driving our results as highly unlikely because of a number of reasons. First, for the invoicing currency to be different from the pricing currency, European exporters mujst actually set prices in euros, but bill their goods (and receive revenues) in Swiss francs.[43] This option seems quite unlikely, since that strategy would expose the exporters to exchange rate risk between the invoice date and the actual payment, while the choice of invoicing currency is usually motivated to avoid exchange rate risk.[44][45]

Second, under the assumption that misclassified invoicing currencies were driving the results, the ERPT would be truly instantaneous and identical on each single day after the shock, as approximately the same share of transactions are misclassified each day.[46] We observe, however, that there is virtually no price effect on January 16^{th} as well as a gradual increase in the pass-through in the following days.[47]

Third, the potential misclassification should be expected to affect euro-invoiced imports at least as much as Swiss franc-invoiced goods. In that case, a corresponding partial pass-through rate should emerge in the sample with euro-invoicing. The top panel of Figure 6 shows, instead, that a pass-through

[43]The default invoicing currency is in euros and firms must verify through the actual bills, whenever they report Swiss franc as invoicing currency.

[44]See Friberg and Wilander (2008), who present survey data from Swedish exporters showing that less than 10% of firms answer that less than 90% of their export revenue is priced and invoiced in the same currency.

[45]In section C.3 of the Online Appendix, we show that for a range of value where there is an incentive for importers to ask for the invoice to be in CHF to simplify importing procedures, there is no observed abnormal invoicing pattern.

[46]The number of transactions is around $50,000$ per day.

[47]See also Figure 16 in section G of the Online Appendix, showing the evolution of the pass-through.

rate of one, which strongly suggests that the invoicing currency is correctly recorded in our sample with euro invoicing. We see no apparent reason for asymmetric misclassification favoring Swiss franc invoicing. Nevertheless, exporting firms might still have the particular tendency to price in their domestic currency and invoice in the destination currency. Such a tendency, however, should also apply to Swiss firms exporting to the euro area so that part of our export observations classified as euro-invoiced are actually priced in Swiss francs. We should thus observe an artificially low (i.e., partial) pass-through in the exports invoiced in euros. Since we observe full pass-through for exports invoiced in euros, there seems to be no general pattern that firms price in their domestic currency but invoice in the destination currency.[48]

Fourth, direct evidence on the frequency of price changes confirms that the frequency of adjustment in the CHF increased right after the exchange rate shock. Figure 8 plots the year-on-year change in the shares of price changes within the sample of import prices surveyed by the Federal Statistical Office to construct the Swiss import price index.[49] The left 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.[50] The right panel plots the corresponding shares of price changes for the sample of goods invoiced in foreign currency.[51] In line with our interpretation of Figure 6, the increase in the share of price changes is much more moderate for the sample of goods invoiced in foreign currencies.

Also, the relatively low frequency of price adjustment in the Swiss franc sample *before* the price shock flatly contradicts misclassification. Specifi-

[48] In Section 4.3 we attributed the imperfect pass-through in the first few working days after the shock to the fact that the value of exports invoiced in euros can be converted using either the daily exchange rate or a monthly average.

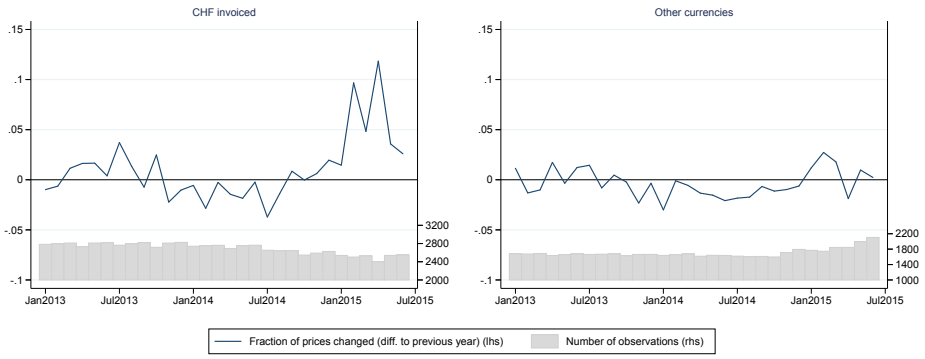
[49] We use year-on-year changes because the sample of prices is specific to each month of the year. The sample includes goods from all partners and not only from the euro area. Surveys are conducted within the first eight days of each month and are reported at the monthly frequency. January 2015 data thus refer to the period before the shock.

[50] The average share of changed 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. We attribute the staggered increase in the reported frequency of price changes to the fact that the survey in February and March cover sub-samples of products only. Thus, some of the prices that changed in January may not have been surveyed before March or April. Corresponding price changes appear in the statistics with a delay.

[51] This sample also includes the small share of goods invoiced in USD and other foreign currencies and covers all partner countries.

cally, roughly half of the observations in the CHF/sample would be required to be misclassified to rationalise our estimated pass-through of about 0.5. Since exchange rates are subject to constant shocks also in normal times, a share of 0.5 of invoicing misclassification would imply that at least half of the prices change every single time they are recorded.[52] Hence, under misreporting, the frequency of adjustments necessarily exceeded 0.5. Instead, the frequency of adjustment within the CHF sample was only 0.22 in 2014, refuting alleged misclassification, even in the case that misclassification affected our CHF-sample only.

Figure 8: Monthly frequency of price adjustment



Sources: Federal Statistical Office, section for the import price index.

Finally, recent studies using on survey-based price data, also confirm an increase in the frequency of adjustment in the CHF after the exchange rate (see Auer et al. (2017) and Kaufmann and Renkin (2017)). Overall, these findings based on different data sources indicate that misclassification of invoicing currencies can be safely refuted as the reason for the estimated fast, partial exchange-rate pass-through.

4.5.3 Inference from repeated cross-section

Another potential concern is that our estimates effectively rely on repeated cross-section data of unit values. Our interpretation regarding price changes, instead, appeals to models that make predictions along the time-dimension

[52] A mechanical conversion at market exchange rates would imply that a price change is recorded almost surely at every single date the price appears in the statistic.

and should therefore be tested with time-series data as used in Gopinath and Itskhoki (2010) or Auer and Schoenle (2016).

We respond to these objections as follows. First of all, acknowledge that we do not identify price changes. Instead, our estimated coefficient on the k^{th} daily dummy reveals the difference between the realised average unit value on day k after the shock and an unbiased predictor of a triplet's average unit value on day k under all information available prior to the exchange rate shock. In the absence of the substitution effects discussed above, our regression informs about the difference between the realisation of post-shock transaction prices and their expectations right before the shock. A statistically significant difference constitutes indirect evidence that firms' price plans for transactions on day k after the shock were revised between the date of the shock and the actual transaction date k. In this narrow sense, our analysis identifies revisions or *adjustments* of price plans.

We argue, however, that this statistical identification of revisions of price plans (i.e., of price adjustments) is the suitable methodological tool *even* when actual price data are available. To make our case, we observe that, measuring the speed of ERPT, we are ultimately interested in the date when price plans are revised, not in the date at which a transaction with a new price takes place. Yet, as import transaction are typically recoded at a low frequency only, exact dates are impossible to pin down even with price data. For example, for a firm-identified subsample of the Swiss customs data for 2007, Kropf and Sauré (2014) report an average frequency of shipments of 3.5, or one shipment every 100 days.[53] Given these numbers, a new price (or "observed" price adjustment) only indicates that price plans were changed between the dates of two consecutive transactions – i.e., sometime within the preceding quarter for the average product imported by Switzerland. Given this rough time grid, we must turn to our statistical inference based on the unbiased predictor of a triplet's average price on day k, under all information available prior to the exchange rate shock.

4.5.4 Summary of concerns

The sum of our observations indicate that the fast ERPT is not a spurious result driven by poor data.[54] We therefore claim that our earlier interpretation that the fast ERPT is driven likely by underlying nominal price

[53] See Hornok and Koren (2015) for evidence from French firms.

[54] In Section A7 of the Online Appendix, we dicuss our definition of the start- and end date of adjustment and provide additional details of the transition period. We reiterate that we take our estimates of start and end day as indications only.

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) indicate that highly productive firms display relatively low import price ERPT, while Amiti et al. (2014) show that import-intensive exporters display relatively low ERPT. Certain firms may have adjusted their price one-to-one with the exchange rate, whereas others did not adjust prices at all. Consequently, our preferred interpretation of the estimation results runs as follows. The majority of firms that adjusted prices in reaction to the exchange rate shock did so within the very short period of two weeks after the shock. In other words, if a firm's optimal response to the exchange rate shock was to change its border price, this price change was implemented very quickly.

One question that remains is how the rapid adjustment of border prices occurred in practice. After all, contracts and the physical delivery of cross-border transactions are typically understood to have substantial time lags, very often exceeding the two weeks of inferred price adjustments (see Amiti and Weinstein (2011)) To address this question, we turn to informal information obtained through interviews conducted by delegates of the SNB regional network.[55] The interviews suggest that Swiss managers did adopt unconventional measures to adjust to the appreciation of the Swiss 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 certain 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.[56]

5 Robustness checks

This section presents a series of robustness checks on the previous section's main finding that the adjustment of unit values to the large exchange rate shock is remarkably fast. The speed of ERPT is high for our numerous

[55]The SNB delegates conduct quarterly interviews with 230 managers and entrepreneurs on the current and future economic situation. See the SNB's Quarterly Bulletins for details.for example.

[56]Some Swiss exporters with weak bargaining positions fully absorbed the exchange rate shock through price reductions to defend their market shares. In certain cases, prices were even renegotiated for goods that were purchased before the shock but whose delivery was still outstanding because of delivery lags.

cuts through the data: in all robustness checks, 80% of the medium-run pass-through is reached within 10 working days at most.

With the robustness checks we address potential concerns that are broadly related to data limitations and to firm-specific and product-specific characteristics. All robustness checks are based on specification (1).

As our main focus concerns the speed of the ERPT, we conduct our robustness on the sample of Swiss franc invoiced imports, presented in the bottom panel of Figure 6. All results (in particular the start- and end-day) are summarised in Table 3.[57] The corresponding graphs of the daily price dynamics are relegated to the Online Appendix J.

Table 3: Daily regression results (specification 1) for CHF invoiced import transactions

Sample	Start day	End day	Start day PT	Med-run PT	Obs.
1) baseline	2 (1 2)	12 (8 17)	0.32 (.007)	0.61 (.003)	8608997
2) sup. units.	2 (1 2)	9 (7 13)	0.38 (.0118)	0.58 (.006)	2273988
6) cons. goods	2 (1 2)	7 (7 13)	0.49 (.008)	0.74 (.004)	4489617
7) invest. goods	2 (1 4)	11 (8 21)	0.13 (.011)	0.47 (.005)	4086878
8) interm. goods	2 (1 4)	12 (6 25)	0.29 (.014)	0.59 (.006)	1846694
9) diff. goods	2 (1 2)	8 (7 16)	0.30 (.007)	0.60 (.003)	7699880
10) ref. goods	2 (1 4)	9 (4 13)	0.27 (.019)	0.63 (.009)	614508
11) org. exchange	5 (1 7)	12 (1 20)	0.45 (.040)	0.92 (.026)	53824
12) single trans.	2 (1 2)	2 (2 7)	0.47 (.015)	0.51 (.006)	2165578
15) high var. triplets	2 (1 4)	10 (5 17)	0.28 (.021)	0.72 (.009)	1993539
16) low var. triplets	2 (1 2)	8 (3 19)	0.22 (.007)	0.56 (.004)	1246369
17) high intraf. (noga)	1 (1 3)	4 (2 9)	-0.25 (.022)	0.53 (.012)	521746
18) low intraf. (noga)	2 (1 2)	7 (2 19)	0.53 (.014)	0.82 (.008)	1544136
19) high intrafirm (census)	3 (1 3)	9 (3 11)	0.35 (.)	0.57 (.)	580933
20) low intrafirm (census)	2 (1 2)	6 (2 13)	0.54 (.)	0.63 (.)	1391565
Exports (baseline)	2 (1 7)	11 (9 16)	0.03 (.009)	0.38 (.004)	5865536

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 represents the first day where 90% of the medium-run pass-through has been achieved. Standard errors or 95% bootstrap confidence intervals are shown in parenthesis. The baseline specification is the one described in Section 4.1. The following subsamples are used for each of the other specifications presented in this table: 2. augmented 8-digits HS code for which a precise unit of measure is available; 6. 8-digit HS codes classified as a consumption goods (OZD classification); 7. 8-digit HS codes classified as investment goods (OZD classification); 8. 8-digit HS codes classified as intermediate goods (BEC classification); 9. differentiated goods (Rauch (1999) classification); 10. Reference priced goods (Rauch (1999) classification); 11. Goods traded on an organised exchange (Rauch (1999) classification); 12. customs declarations with a single transaction; 15. triplets where unit value variance is in the top 25th percentile; 16. triplets where unit value variance is in the bottom 25th percentile; 17. HS goods that fall in NOGA codes where more than 75% of firms report being engaged in intrafirm trade in the data from Fischer, Lutz and Walti (2007) 18. HS goods that fall in NOGA codes where less than 25% of firms report being engaged in intrafirm trade in the data from Fischer, Lutz and Walti (2007)

[57] Table 8, in the Online Appendix, shows the corresponding information for export regressions.

5.1 Unit values versus unit prices

One common critique of analyses based on unit values is that these measures constitute an imprecise and potentially biased proxy of the underlying prices. In addition to our detailed discussion in Section 4.5.1, we address these concerns in two ways. First, we restrict the sample to those products and observations for which information on 'supplementary units' is available. These units represent the economically relevant accounting measure for the goods. Typical units are "pairs" (e.g., for shoes) and "pieces" (e.g., for watches).[58] The resulting measures, which we label *unit prices*, are arguably a better measures of prices.

Row 2 in Table 3 shows that estimations based on unit prices reveal a similar speed of the pass-through as in the baseline, as most of the medium-run ERPT is attained after 9 working days. A significant pass-through of 0.38 is already achieved after two working days.[59]

Still concerned about potential substitution within a triplets, we run our regression on two further sub-samples: those with a high variability of unit values (the 75^{th} percentile regarding within triplet variation in 2014) and those with a low variability (the 25^{th} percentile). Rows 15 and 16 report that in both cases, the medium-run pass-through is achieved after 8 working days already. Also, the high variance sample exhibits a medium run pass-through of 0.72, while the low variance sample has a medium run pass-through of 0.56. These results point to a moderate bias due to substitution.

5.2 Intra-firm trade

Another concern relates to intra-firm trade. Indeed, the headquarter to many European companies are located in Switzerland, while production takes place abroad. To the extent that the ERPT of intra-firm trade may be genuinely different from the pass-through under arm's length trade, related effects could affect our estimations.

We address these concerns in two different ways. First, we use the data collected and documented in Fischer et al. (2007) to identify those Swiss export industries that are most ($> 75\%$), respectively least ($< 25\%$), affected

[58] For example, whereas declarations for certain motor parts only provide information on the mass rather than the number of parts, declarations for watches provide more precise information regarding the number of units.

[59] In table 9 in section A.4 of the Online Appendix, we also show the other robustness checks restricted to observations where supplementary units are available.

by intra-firm trade.[60] Assuming that goods most affected by intra-firm trade are similar for imports and exports, we run our baseline estimations separately for these different subsets of the Swiss franc invoicing goods. Rows 17 and 18 show that for goods with a high (low) intrafirm incidence. In both cases, the start and end days are within the first two weeks, indicating a fast ERPT.

Second, we use an alternative classification of sectors into those most and those least affected by intra-firm trade, based on U.S. Census data on related party trade in U.S. imports from the euro area and based on the assumption that on the product-level, Swiss imports are similarly affected by intra-firm as U.S. imports. Rows 19 and 20 in Table 3 report the results. Again, the estimations indicate that the speed of ERPT is similarly fast in both cases.

Finally, we point out that the results in Neiman (2010) indicate that the speed of the ERPT is higher but not faster for intra-firm transaction (see Figure 3 in Neiman (2010)). Thus, the documented speed of ERPT are still surprising even if it partly relied on intra-firm trade.

5.3 Broad Good classes

It might be conjectured that the prices of specific broad goods classes, such as investment goods or homogeneous, or reference-priced goods react particularly fast to exchange rate shocks. If these goods are over-represented in the Swiss franc sample, our estimates of the fast speed of adjustment could be misleading. We therefore run our regression separately for consumption goods, investment goods and raw materials, and intermediate goods.[61] Rows 6, 7, and 8 in Table 3 show the start and end days with the pass-through estimates for consumption (row 5), investment goods and raw materials (6), and intermediate goods (7).[62] Some heterogeneity in the medium-run level of pass-through is uncovered, but again, the results suggest that the ad-

[60] The data from Fischer et al. (2007) are classified by NOGA 2 digit codes, which are directly mapped into ISIC classification, and further into HS codes using the correspondence table from HS to ISIC published by the World Bank.

[61] 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.

[62] In the Online Appendix J, Figure 23 shows the daily estimates on import unit values for the investment goods and raw material, Figure 22 presents those for consumption goods and Figure 24 presents the estimates for intermediate goods.

justment begins rapidly and reaches most of its medium-run pass-through estimate within ten working days after the shock.

Similarly, we run separate regressions using the Rauch (1999) classifications of differentiated, referenced, and homogeneous goods.[63] The results, presented in rows 8 to 10 in Table 3, show that the level of pass-through differs for each category. Consistent with earlier work, 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. Differentiated goods as well show a reaction in unit values the second working day after the shock, reaching their medium-term level after eight working days.[64]

We also investigate whether the speed of price adjustment differs across HS categories, running separate regressions for each HS section. Table 4 presents the according results, which show substantial heterogeneity in the medium-run pass-through, with two categories showing no significant medium-run pass-through and other displaying full-pass-through.[65]

Whenever the pass-through is nontrivial, however, the medium-run pass-through is reached within a short time window.[66]

5.4 Precision of currency recording

In our description of the Swiss customs data, we have considered the possibility that the invoicing currency may be misreported for certain transactions. Specifically, each customs declaration has a unique invoicing currency but may contain multiple transactions. In such cases, the invoicing currency of the main transaction is recorded, possibly inducing biased estimates. To address these concerns, we run the baseline regression but restrict the sample to transactions for which a such misclassified invoicing currency can be excluded, using customs declarations with a single transaction only. The results are listed as restriction 12 in Table 3. Consistent with some currency misclassification, they show a slightly lower pass-through than the full

[63] 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).

[64] In the Online Appendix J, Figure 25 shows the daily estimates on unit values. Notably, the exclusion of the more volatile organized exchange and reference categories leads to more precise estimates of the daily reaction.

[65] Section XIX and XXI, ("Arms and ammunitions" and "Works of art"), are ignored because they lacks sufficient observations to estimates daily dummies.

[66] In the Online Appendix J, Figure 27 shows the median of the section specific daily point estimates and confidence intervals.

Table 4: Daily regression results (specification 1) for CHF invoiced import transactions, by HS sections

Section	Start day	End day	Start day PT	Med-run PT	Obs.
Live animal; animal pro∼s	2 (1 7)	4 (2 7)	0.32 (.041)	0.69 (.014)	35222
Vegetable products	2 (1 7)	8 (2 12)	0.33 (.023)	0.49 (.008)	300599
Animal or vegetable fat∼l	4 (1 10)	7 (2 13)	0.65 (.076)	0.88 (.024)	9546
Prepared foodstuff; bev∼s	2 (1 2)	3 (3 8)	0.34 (.012)	0.69 (.005)	769426
Mineral products				-0.07 (.010)	73754
Products of the chemica∼i	2 (1 6)	4 (1 9)	0.16 (.028)	0.58 (.009)	686250
Plastics and articles t∼r	2 (1 5)	14 (2 23)	0.52 (.036)	0.98 (.009)	577906
Raw hides and skins, le∼u	1 (1 4)	4 (1 8)	0.65 (.047)	1.02 (.017)	142165
Wood and articles of wood	3 (1 8)	8 (3 15)	0.59 (.060)	1.21 (.016)	75042
Pulp of wood or of othe∼s	2 (1 3)	2 (1 4)	0.51 (.029)	0.54 (.009)	626366
Textiles and textiles a∼s	2 (1 2)	2 (2 9)	0.68 (.028)	0.70 (.011)	937732
Footwear, headgear, umb∼s	1 (1 3)	3 (1 8)	0.55 (.045)	1.17 (.015)	196529
Articles of stone, plas∼e	2 (1 5)	8 (3 19)	0.30 (.029)	0.83 (.009)	222692
Natural or cultured pea∼c	2 (1 2)	2 (1 2)	3.86 (.155)	2.22 (.033)	51872
Base metals and article∼e	3 (1 7)	8 (3 16)	0.37 (.022)	0.69 (.008)	682905
Machinery and mechanica∼a	3 (1 8)	8 (2 10)	0.22 (.018)	0.39 (.008)	1579400
Vehicle, aircraft, vess∼a				0.21 (.012)	709586
Optical, photographic, ∼g	4 (1 9)	4 (2 7)	0.41 (.031)	0.43 (.010)	432077
Miscellaneous manufactu∼c	2 (1 3)	5 (3 8)	0.36 (.025)	0.89 (.008)	499253

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 represents the first day where 90% of the medium-run pass-through has been achieved. Standard errors or 95% bootstrap confidence intervals are shown in parenthesis. For "vehicle, aircraft and vessels", there is no start day within the daily window.

sample. However, they also show that the speed of adjustment is rapid even in those cases where currency misclassification is impossible, because the medium-run pass-through is reached after only a few days in both cases.[67]

6 Conclusion

This paper analyzes the speed of ERPT for tradable goods to an unusually sharp and *clean* exchange rate shock. A data set recording import transactions at the daily frequency allows us to precisely track the dynamics of pass-through into import prices. The exogenous shock originates from the SNB's decision to terminate the minimum exchange rate policy, which resulted in a permanent appreciation of the Swiss franc of more than 11% against the euro. Our main findings are twofold. First, for goods invoiced in euros, the ERPT is complete and equal to one the day after the ex-

[67] In the Online Appendix J, Figure 26 show the daily results for transactions in which currency misclassification is not possible for imports.

change rate shock and throughout the period to up to six months. Second, for goods invoiced in Swiss francs, the ERPT is partial and extremely fast. Unit values begin to adjust on the second working day after the shock and after eight working days the ERPT, most of the ERPT six months later has been achieved. Loosely speaking, two weeks after the shock the transition period of the ERPT ends. We further show that, while the rate of pass-through is not uniform across various subsets of product groups, the speed of adjustment is very high in virtually all sub-samples.

Together, our two main findings confirm earlier work that the invoicing currency in an important determinant of the ERPT. Importantly, they provide rare evidence of an ERPT with a high degree of confidence in the causal nature of the underlying adjustment. Our results are also consistent with the literature that argues that, adjustments of border prices appear to depend strongly on the nature of the exchange rate shock. Previous literature has often focused on adjustments in response to frequent and small exchange rate shocks, showing that the pass-through tends to be slow. We document that the ERPT is fast for the large shock to the EURCHF exchange rate. These observations may prove crucial for our understanding of how firms to large shocks.

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Online Appendix

to *The Speed of Exchange Rate Pass-Through*

by

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A Tables

A.1 Invoicing shares by section

Table 5: Invoicing currency and shares by sections for imports (value based)

	Share of imports	CHF	EURO	Other
Live animal; animal pro∼s	0.01	0.08	0.91	0.01
Vegetable products	0.02	0.18	0.82	0.00
Animal or vegetable fat∼l	0.00	0.07	0.91	0.02
Prepared foodstuff; bev∼s	0.04	0.20	0.76	0.04
Mineral products	0.08	0.71	0.27	0.01
Products of the chemica∼i	0.25	0.44	0.55	0.02
Plastics and articles t∼r	0.05	0.16	0.84	0.00
Raw hides and skins, le∼u	0.01	0.21	0.74	0.05
Wood and articles of wood	0.01	0.14	0.86	0.00
Pulp of wood or of othe∼s	0.03	0.25	0.75	0.00
Textiles and textiles a∼s	0.02	0.21	0.78	0.01
Footwear, headgear, umb∼s	0.01	0.16	0.82	0.02
Articles of stone, plas∼e	0.02	0.15	0.84	0.00
Natural or cultured pea∼c	0.04	0.31	0.64	0.05
Base metals and article∼e	0.08	0.14	0.86	0.01
Machinery and mechanica∼a	0.16	0.17	0.81	0.03
Vehicle, aircraft, vess∼a	0.10	0.54	0.43	0.03
Optical, photographic, ∼g	0.05	0.26	0.72	0.02
Arms and ammunition; pa∼a	0.00	0.13	0.86	0.00
Miscellaneous manufactu∼c	0.03	0.15	0.84	0.01

Table 6: Invoicing currency and shares by sections for imports (by no of transactions)

	Share of imports	CHF	EURO	Other
Live animal; animal pro∼s	0.02	0.08	0.91	0.01
Vegetable products	0.05	0.22	0.78	0.00
Animal or vegetable fat∼l	0.00	0.19	0.81	0.00
Prepared foodstuff; bev∼s	0.07	0.36	0.63	0.00
Mineral products	0.01	0.26	0.73	0.01
Products of the chemica∼i	0.08	0.33	0.67	0.01
Plastics and articles t∼r	0.07	0.29	0.70	0.01
Raw hides and skins, le∼u	0.02	0.36	0.64	0.01
Wood and articles of wo∼	0.01	0.21	0.79	0.00
Pulp of wood or of othe∼s	0.06	0.40	0.60	0.01
Textiles and textiles a∼s	0.11	0.32	0.68	0.00
Footwear, headgear, umb∼s	0.03	0.28	0.71	0.00
Articles of stone, plas∼e	0.03	0.26	0.73	0.00
Natural or cultured pea∼c	0.01	0.35	0.64	0.01
Base metals and article∼e	0.09	0.27	0.72	0.01
Machinery and mechanica∼a	0.19	0.31	0.67	0.02
Vehicle, aircraft, vess∼a	0.05	0.52	0.46	0.02
Optical, photographic, ∼g	0.04	0.37	0.62	0.01
Arms and ammunition; pa∼a	0.00	0.12	0.88	0.00
Miscellaneous manufactu∼c	0.07	0.27	0.73	0.00

A.2 Export summary statistics

Table 7: Summary statistics for export transactions

	Total sample	Pre-shock	Post-shock
Exports (Switzerland to Euro area)			
Based on transactions			
Average unit value (log)	4.259	4.283	4.209
	(2.641)	(2.033)	(2.646)
Share invoiced in EUR	0.614	0.616	0.611
Share invoiced in CHF	0.371	0.370	0.375
Share invoiced in other currencies	0.014	0.014	0.014
Share with available supp. units	0.221	0.219	0.227
Based on (log) value			
Share invoiced in EUR	0.650	0.651	0.646
Share invoiced in CHF	0.316	0.315	0.318
Share invoiced in other currencies	0.034	0.034	0.036
Share with available supp. units	0.216	0.216	0.216
Number of transactions	16266000	19762575	5170038
Average number of daily transactions	29845.87	29276.95	31144.81
	(20568.54)	(20282.17)	(21212.93)

Note: standard deviations are shown in parentheses. The total sample spans from January 1, 2014 to June 30, 2015. The pre-shock period extends from January 1, 2014 to January 15, 2015, whereas the post-shock period is from January 16, 2015 to June 30, 2015.

A.3 Export regression table

Table 8: Daily regression results (specification 1) for CHF invoiced export transactions

Sample	Start day	End day	Start day PT	Med-run PT	Obs.
1) baseline	2 (1 7)	11 (9 16)	0.03 (.010)	0.38 (0.004)	5865536
2) sup. unit	3 (1 7)	12 (11 13)	0.17 (.012)	0.51 (0.006)	1588230
3) big imp.	2 (1 10)	10 (2 15)	0.23 (.021)	0.41 (.009)	1170862
4) value>300	4 (1 7)	11 (7 16)	0.15 (.011)	0.36 (.005)	2636914
5) value<300	1 (1 7)	8 (3 15)	0.19 (.013)	0.40 (.006)	3193044
6) cons. goods	2 (1 3)	12 (10 13)	0.13 (.011)	0.51 (.006)	2052150
7) invest. Goods	1 (1 8)	9 (1 11)	0.17 (.014)	0.31 (.005)	3801384
8) interm. Goods	4 (1 10)	8 (1 12)	0.16 (.023)	0.37 (.010)	1345541
9) diff. goods	3 (1 7)	12 (8 16)	0.14 (.010)	0.38 (.004)	5232405
10) org. exchange	4 (1 14)	12 (1 17)	0.49 (.042)	0.97 (.034)	50760
11) ref. priced	2 (1 9)	3 (1 11)	0.33 (.020)	0.41(.014)	371639
12) single trans,	3 (1 11)	3 (1 11)	0.28 (.021)	0.24 (.009)	1160030
13) transp. by road	1 (1 7)	11 (7 19)	0.12 (.010)	0.38 (.004)	4777974
14) high var. triplet	4 (1 9)	7 (1 9)	0.23 (.024)	0.32 (.010)	1966191
15) low var. triplet	2 (1 10)	13 (10 15)	0.08 (.008)	0.41 (.005)	516405
16) high intrafirm (noga)	3 (1 7)	3 (3 13)	0.51 (.022)	0.57 (.014)	457836
17) low intrafirm (noga)	2 (1 12)	11 (2 13)	0.25 (.024)	0.53 (.013)	729089
18) high intrafirm (census)	3 (1 7)	3 (3 13)	0.51 (.022)	0.57 (.014)	457836
19) low intrafirm (census)	2 (1 12)	11 (2 13)	0.25 (.024)	0.53 (.013)	729089

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 represents the first day where 90% of the medium-run pass-through has been achieved. Standard errors or 95% bootstrap confidence intervals are shown in parenthesis. The baseline specification is the one described in Section 4.1. The following subsamples are used for each of the other specifications presented in this table: 2. augmented 8-digits HS code for which a precise unit of measure is available; 3. 8-digits HS code - postal code triplets which have the largest shares of total imports and whose collective share is larger than two-thirds; 4. transactions with value larger than CHF 300; 5. transactions with value smaller than CHF 300; 6. 8-digit HS codes classified as a consumption goods (OZD classification); 7. 8-digit HS codes classified as investment goods (OZD classification); 8. 8-digit HS codes classified as intermediate goods (BEC classification); 9. differentiated goods (Rauch (1999) classification); 10. Reference priced goods (Rauch (1999) classification); 11. Goods traded on an organised exchange (Rauch (1999) classification); 12. customs declarations with a single transaction; 13. transactions of goods transported by road; 14. triplets where unit value variance is in the top 25th percentile; 15. triplets where unit value variance is in the bottom 25th percentile; 16. HS goods that fall in NOGA codes where more than 75% of firms report being engaged in intrafirm trade in the data from Fischer, Lutz and Walti (2007) 17. HS goods that fall in NOGA codes where less than 25% of firms report being engaged in intrafirm trade in the data from Fischer, Lutz and Walti (2007)

A.4 Unit price regression tables

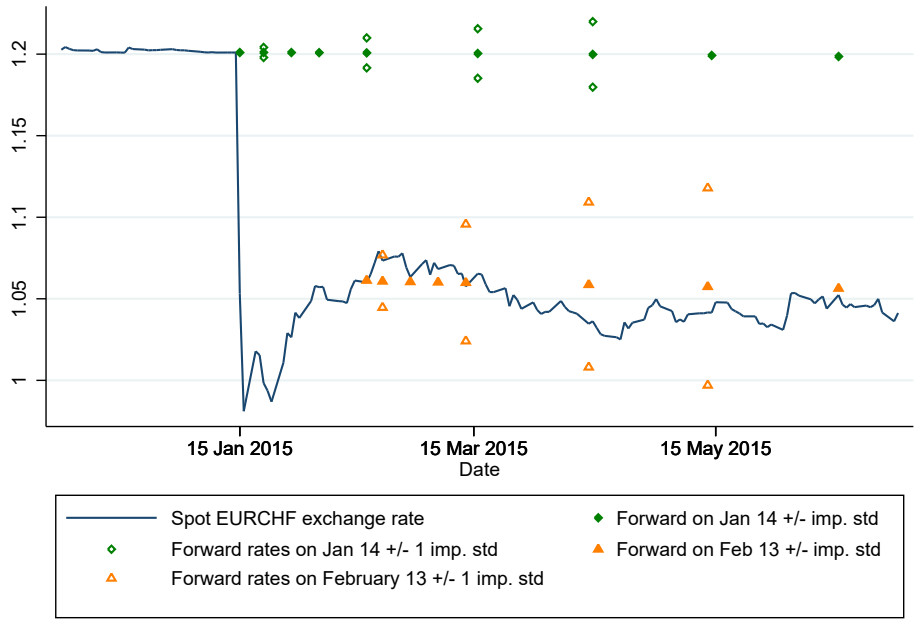
Table 9: Daily regression results (specification 1) for CHF invoiced import transactions where supplementary units are available

Sample	Start day	End day	Start day PT	Med-run PT	Obs.
1) baseline	2 (1 2)	9 (7 13)	0.38 (.012)	0.58 (.006)	2273988
2) big importer	3 (1 11)	19 (3 22)	0.20 (.019)	0.48 (.010)	516335
3) value>300	2 (1 6)	12 (4 19)	0.16 (.013)	0.38 (.006)	1062977
4) value<300	1 (1 2)	9 (7 12)	0.23 (.015)	0.76 (.008)	1165613
5) cons. goods	2 (1 2)	12 (2 17)	0.59 (.011)	0.81 (.007)	1437444
6) invest. goods	6 (1 8)	6 (1 8)	0.42 (.022)	0.21 (.012)	813984
7) interm. goods	1 (1 13)	1 (1 13)	0.44 (.036)	0.48 (.019)	224350
8) single trans.	2 (1 6)	3 (1 8)	0.36 (.025)	0.42 (.010)	656794
9) transp. by road	1 (1 2)	9 (8 12)	0.16 (.012)	0.62 (.007)	1980772
10) high triplet var	2 (1 2)	9 (7 12)	0.38 (.012)	0.58 (.006)	2107934
11) low triplet var	3 (1 4)	14 (4 29)	0.22 (.013)	0.42 (.008)	466714
12) high intrafirm (noga)	5 (1 18)	5 (2 8)	0.60 (.059)	0.53 (.027)	71811
13) low intrafirm (noga)	2 (1 9)	1 (1 6)	1.43 (.142)	0.62 (.036)	47389
Exports	3 (1 7)	12 (11 13)	0.17 (.012)	0.51 0.006)	1588230

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 represents the first day where 90% of the medium-run pass-through has been achieved. Standard errors or 95% bootstrap confidence intervals are shown in parenthesis. The baseline specification is the one described in Section 4.1. All regressions are using the sample of augmented 8-digits HS code for which a precise unit of measure is available; 2. 8-digits HS code - postal code triplets which have the largest shares of total imports and whose collective share is larger than two-thirds; 3. transactions with value larger than CHF 300; 4. transactions with value smaller than CHF 300; 5. 8-digit HS codes classified as a consumption goods (OZD classification); 6. 8-digit HS codes classified as investment goods (OZD classification); 7. 8-digit HS codes classified as intermediate goods (BEC classification); 8. customs declarations with a single transaction; 9. transactions of goods transported by road; 10. triplets where unit value variance is in the top 25th percentile; 11. triplets where unit value variance is in the bottom 25th percentile; 12. HS goods that fall in NOGA codes where more than 75% of firms report being engaged in intrafirm trade in the data from Fischer, Lutz and Walti (2007) 13. HS goods that fall in NOGA codes where less than 25% of firms report being engaged in intrafirm trade in the data from Fischer, Lutz and Walti (2007)

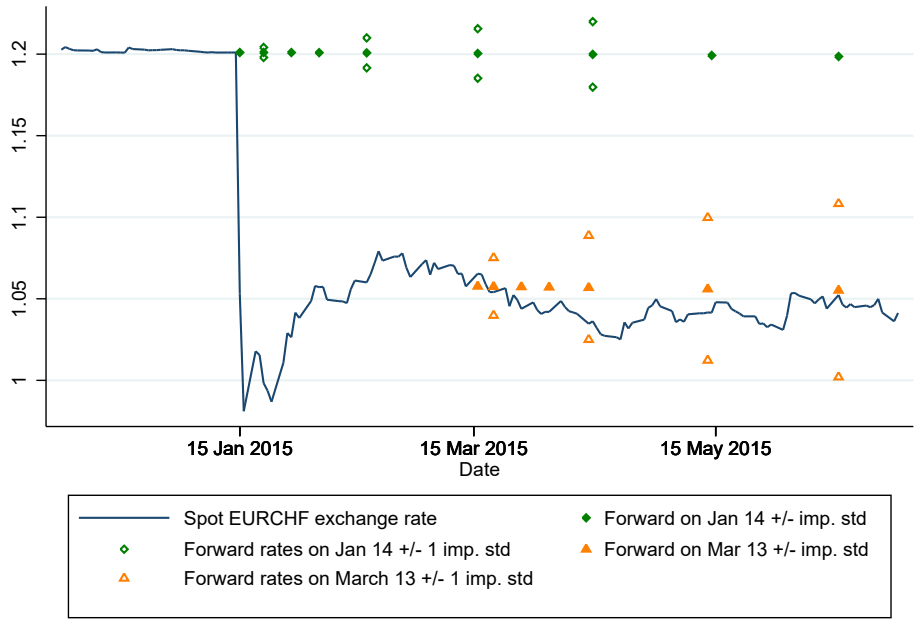
B Additional exchange rate figures

Figure 9: EURCHF spot rates and forward rates February 2015 with implied standard deviations



Sources: SNB, Datastream, own calculations.

Figure 10: EURCHF spot rates and forward rates March 2015 with implied standard deviations



Sources: SNB, Datastream, own calculations.

C Additional properties of the trade data

Our analysis crucially relies on the distinction between the two main invoicing currencies (euros and Swiss francs). Concerns may thus arise that firms switched their invoicing currencies (and thus sample) right after the exchange rate shock. For example, the pass-through of oil products may be high due to the market structure of the international oil market. We describe the stability of invoicing shares in section C.1. In addition, the very choice of invoicing currencies may be impacted by product characteristics that simultaneously determine the ERPT. For example, the pass-through of oil products may be high due to the market structure of the international oil market. It seems therefore important to briefly discuss the determinants of invoicing currencies, as we do in section C.2. Finally, if some firms price their goods in euros but invoice in Swiss francs, the reaction of unit values invoiced in CHF cannot be interpreted as a change in pricing. Thus we discuss the likelihood of this happening in section C.3.

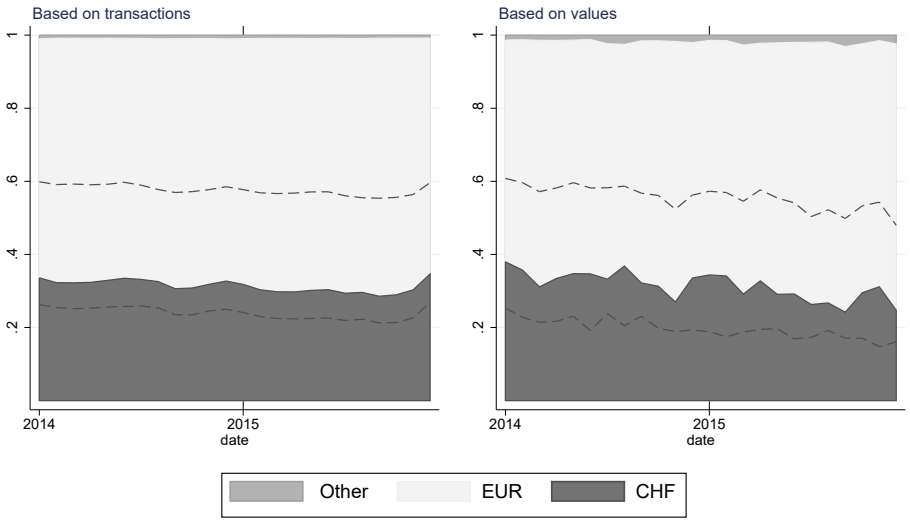
C.1 Stability of invoicing shares

We take first a look at the monthly shares of invoicing currencies and the prevalence of switching currencies after the shock. Figure 11 plots the 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 transactions (left panel) and based on values (right panel). The figure conveys two messages. First, nearly all trade is invoiced either in Swiss francs or euros. Second, the respective shares are stable over time and do not appear to have shifted in response to the exchange rate shock in January 2015.

To assess whether firms are prone to switch the invoicing currency, Figure 11 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 one-quarter and one-half of the respective shares.[68]

[68] See Appendix 2 for further information on the extent of switching from one invoicing currency to another in response to the exchange rate shock.

Figure 11: Monthly shares of currency in Swiss imports from the euro area



The dark area represents the share of transactions (value) invoiced in Swiss francs, the light area represents euro-invoiced transactions and the gray area represents 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 triplet that has invoiced in different currencies.

C.2 Determinants of invoicing currencies

Empirical literature such as Goldberg and Tille (2016) has identified important (e.g., exchange rate volatility, currency transaction volumes), micro-level (e.g. firm-level market shares) and transaction-level (e.g. size) determinants of invoicing currency. A question may thus arise to what extent our two samples – euro and Swiss franc invoiced transactions – reflect different selections of transactions.

We note that the variation of macro-level determinants in our sample is limited to start with, because we only deal with transactions between the euro area and Switzerland. However, to gauge the degree of potential sample selection for our empirical exercise, we investigate whether goods invoiced in euros differ systematically from those invoiced in Swiss francs. In particular, we run a series of regressions of a dummy taking the value one for euro-invoiced transactions on different sets of fixed effect.

Table (10) shows the R-squared of these regressions. The table shows

Table 10: Invoicing regressions

Fixed effect	Regression R2
Country	0.01
Product classification	0.14
Postal code	0.25
Country x product x postal code	0.70

The table shows the R2 of regressions of a dummy equal to 1 for transaction invoiced in euro and 0 for CHF, on different fixed effects.

that product classification and country of origin explain only a small part of the variance in invoicing choice. Postal code explains a larger share of the variance, but still leaves three quarters unexplained. These results imply that focusing on Swiss francs or euro invoiced goods does not bias the sample to a particular set of goods, partner countries, or regions in Switzerland.

Overall, our assessment shows that the separation of the two subsets of transactions (euro invoiced and Swiss franc invoiced) does not decompose the sample into fundamentally different product classes or source countries. Instead, each of the two subsets contains a "representative" mix of products and source countries. The exercise also shows, that a single triplet tends to be associated with a specific invoicing currency.[69]

C.3 Potential invoicing currency misclassification

We can use a specificity of Swiss customs rules that differentiate administrative burden if the invoice is in euros or Swiss francs to check if the probability of euro invoicing is unaffected by such an incentive. For Swiss imports from the European Union to be taxed according to preferential tariffs, the importer needs to prove that the product origin is in the EU. This can be done in a simplified manner if the transaction is less than CHF $10,300$ for transactions invoiced in Swiss francs or less than EUR $6,000$ for transactions invoiced in euros. The reason is that for small transactions, a simple declaration on the invoice is sufficient, while for bigger transactions a certification from an approved registered importer is needed.[70] Hence, importers have an incentive to ask for the invoice to be made in Swiss francs rather than

[69]This last finding is consistent with Chung (2016) and may thus be seen as evidence that our triplets constitute reasonable firm proxies.

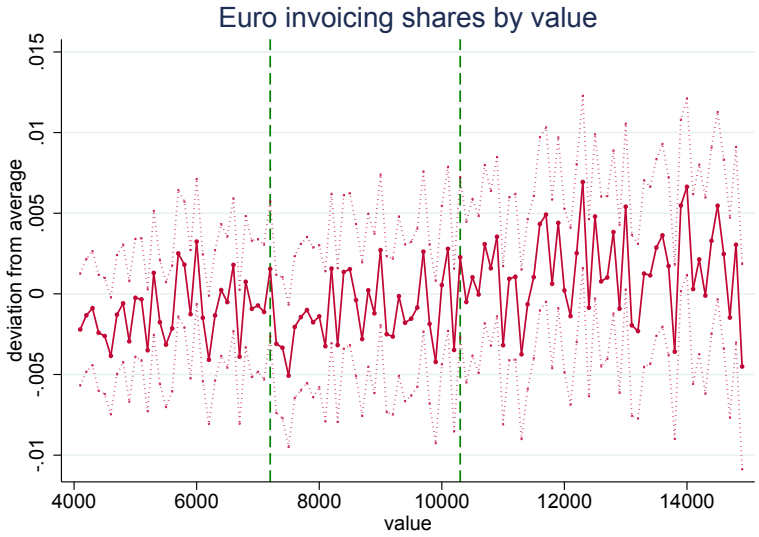
[70]See for example the May 2017 newsletter from the customs office that stresses that the invoicing currency is determinant: https://www.ezv.admin.ch/dam/ezv/de/dokumente/archiv/a5/ursprung/Newsletter_ursprung_1_2017.pdf

euros around these values.

Friberg and Wilander (2008) report that for the small proportion of firms who report invoicing in a different currency than they set their price in (less than 10%), the main reason is that the importer asked for it. Hence, if it is common for firms to invoice in a different currency than they price in, one should expect to find an artificially lower proportion of euro-invoiced transactions when the value of the transaction is between 1.2*6000= CHF 7,200 and CHF 10,300, as the administrative burden of Swiss franc-invoiced transactions for the importer is relatively low. Figure 12 shows the proportion of Euro invoiced transactions in bins of CHF 100 around the cutoffs and shows no abnormal behaviour.

Formally, we regress a dummy equal to 1 if the invoice is in Euro on HS-country-postal code triplet fixed effects and dummies for each 100CHF bins for transactions whose value is between CHF $4,000$ and CHF $15,000$. Figure 12 shows the coefficient on the bin dummies, which represent the deviation from average euro invoicing proportion for transactions whose value is in the bin.

Figure 12: Euro invoicing around the administrative burden cutoffs



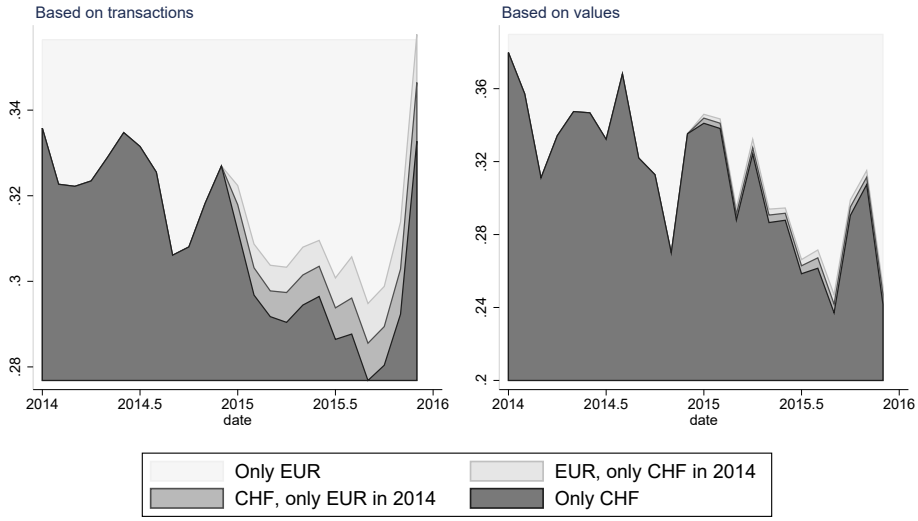
Results from a regression of euro invoicing dummy on dummies for value bins of size 100, including triplet fixed effects.

D 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 indicated 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 is shaded as follows: the dark area is the share of euro invoicing, the light area is the share of Swiss franc invoicing, the light grey is the share of switching from Swiss franc to euro invoicing after January 15, 2015, and the grey area 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 following triplet: postal code, HS product, and partner country.

The results show that the level of switching after January 15, 2015 is particularly low at 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 finding, we conclude that our daily pass-through estimates are not subject to switching effects at the time of the exchange rate shock.

Figure 13: Currency switching in 2015 - Swiss imports from the euro area



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

E Exit and entry around the exchange rate shock

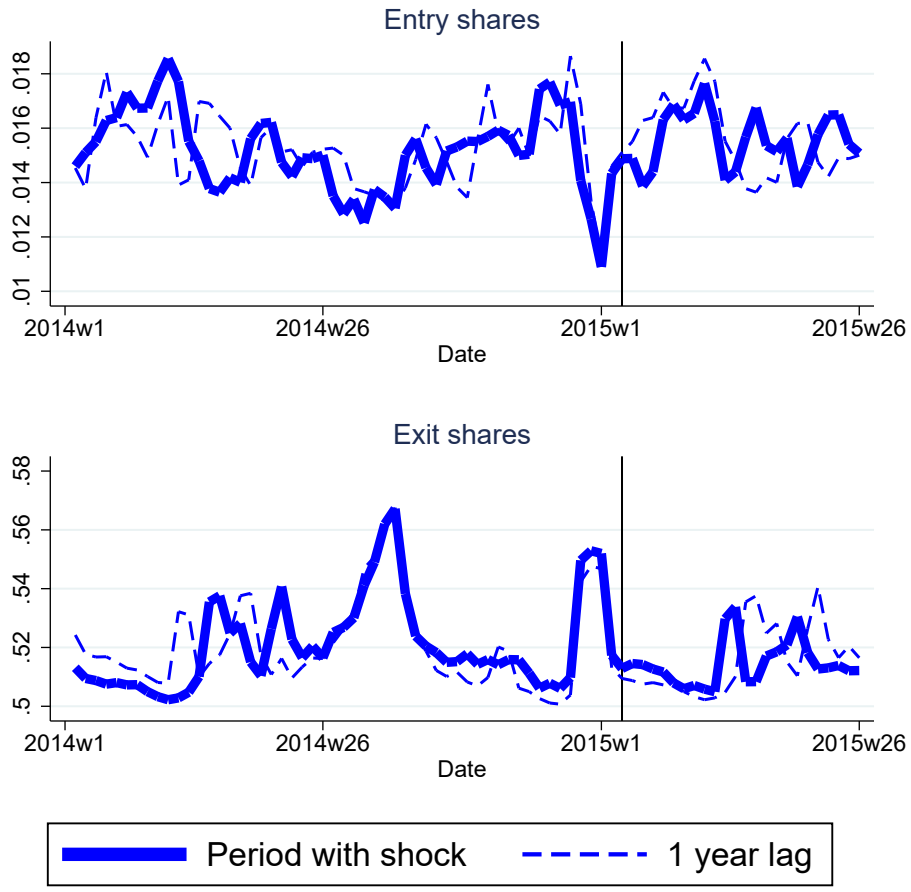
We gauge the rate of exit and entry of products around the date of the exchange rate shock. For each week w, we compute the number of those product-country pairs with positive imports within the two weeks w and $w+1$.[71] Out of these sets of product-country pairs, we compute the share with zero imports in the calendar year before w. This share of *entrants* is plotted in the top panel of Figure 14 (fat solid line). Additionally, a corresponding thin dashed line is added as a 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 identify 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 14 (thick solid line). A corresponding thin dashed line is added as a 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. However, the set of exits and entrants that can be identified (those plotted in Figure 14) do not indicate unusual entrance or exit in the period after the shock within which the adjustment occurs.

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

Figure 14: 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-week window [w,w+1] but not active (active) in the last 52 weeks [w-1,w-52].

F Monthly estimations

The total available sample is from January 2012 to December 2015. Given the high number of transactions that this sample 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 begin 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:

$$\ln(p_{i,t}) = \alpha_i + \sum_{m=0}^{M} \beta_m \ln(e_{t-m}) + \sum_{m=0}^{M} \delta_m \ln(CPI_{i,t-m}) + X_{i,t}\gamma + \varepsilon_{i,t}, \quad (2)$$

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.[72] The bilateral exchange rate e_t is expressed in CHF per EUR. The EZV exchange rate does not carry any index of the partner 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, including the 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 euros and Swiss francs. In all specifications, we cluster standard errors at the postal code level.

Model (2) is specified in levels instead of changes. This choice is motivated by the fact that our data have a strongly unbalanced structure because some triplets do not 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 that are 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 (2).

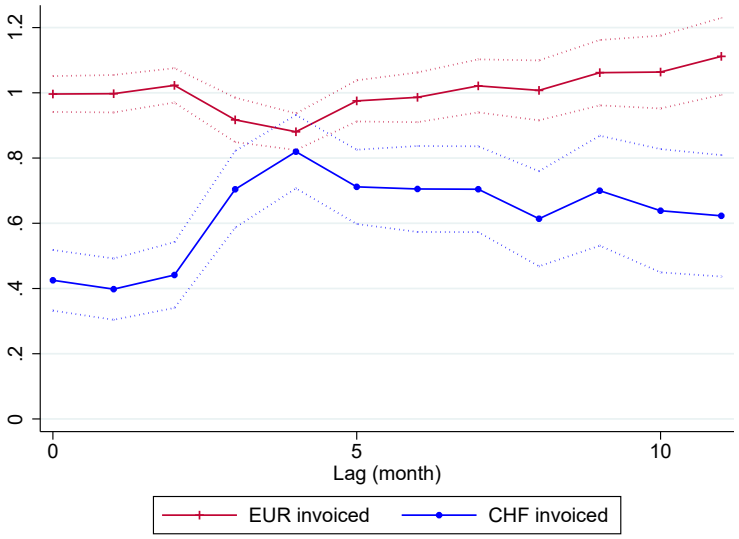
The exchange rate movement during the full sample is composed of the floor period, with little exchange rate variation, the January 15, 2015, shock,

[72] Corresponding estimates for exports corroborate our results regarding the speed of the ERPT. These results are reported in an earlier working paper version of this study, which is available upon request.

and the post-floor exchange rate movements. It is clear from Figure 1 that most of the exchange rate variation is originating from the shock, and that the results of the regression are primarily representing the reaction to the shock.

Figure 15 plots the estimated β_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 represents those invoiced in Swiss francs.

Figure 15: Cumulative pass-through on import unit values



Based on a monthly triplet panel regression including controls for exporter CPI and importer GDP (specification (2)). Errors are clustered at the postal code level. The sample spans from January 2012 to December 2015.

The pass-through into import unit values of euro-invoiced transactions is unsurprisingly equal to 1 for the first lags and remains stable afterward. This finding mirrors the result uncovered in Gopinath et al. (2010) of full and stable pass-through for import transactions invoiced in the foreign currency.

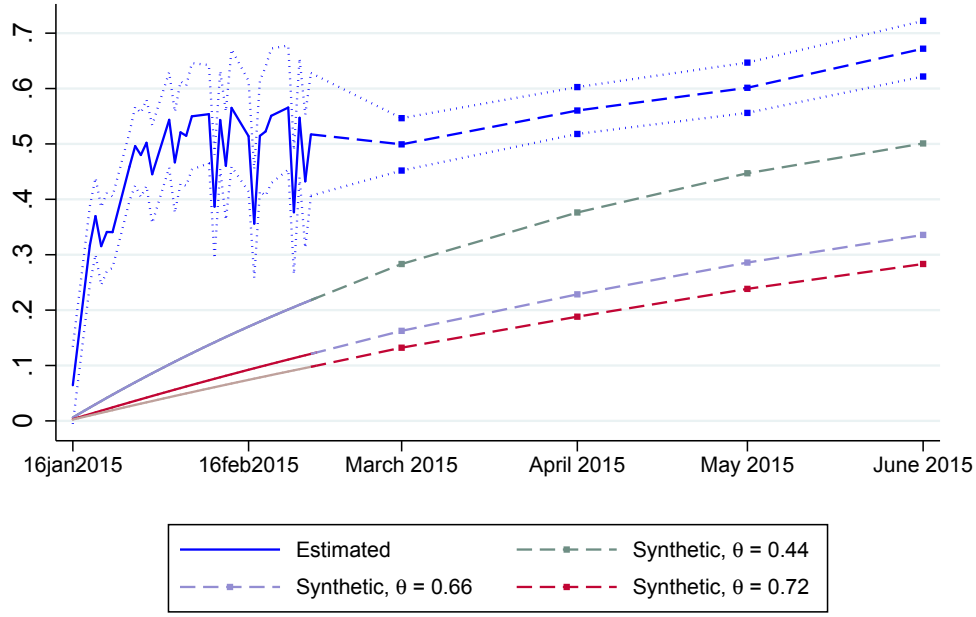
For transactions invoiced in Swiss francs, the results are more surprising. The immediate pass-through of around 0.4 indicates that unit values are reacting to the exchange rate movement within the same month. Even more striking is the fact that the initial pass-through is close to the longer-

run cumulative pass-through of 0.65. This result indicates that a large proportion of the pass-through is attained within the month of the shock rather than with a delay.[73]

G Estimated and Synthetic ERPTs

[73] We stress out that almost all variation in the exchange rate in this sample comes from the January 15 shock.

Figure 16: Exchange rate pass-through - estimated (CHF invoiced) and synthetic (under different Calvo parameters)



Notes: The figure plots different rates of the pass-through after a large and permanent shock. It shows that the estimated pass-through based on daily Swiss micro-data is much faster than any model-implied adjustment process. The blue line corresponds to the pass-through based on our daily and monthly estimates as reported in Figure 6. The other lines correspond to the pass-through implied by a simple price-setting model under a Calvo rule where the fraction θ of all firms cannot adjust prices within a quarter and under the further assumption that prices ultimately converge to our estimated medium-run level. The red line corresponds to a very low degree of import price flexibility with $\theta = 0.72$, which is consistent with the findings for ERPT into Swiss import prices reported in Burstein and Gopinath (2014). The lavender line represents a calibrated Calvo rule of an intermediate degree of price flexibility with $\theta = 0.66$ as in Rotemberg and Woodford (1997). The green line corresponds to higher degree of price flexibility with $\theta = 0.44$, consistent with the estimated Calvo parameter for import prices in Adolfson et al. (2007).

H Days needed to reach a given proportion of the medium-run ERPT

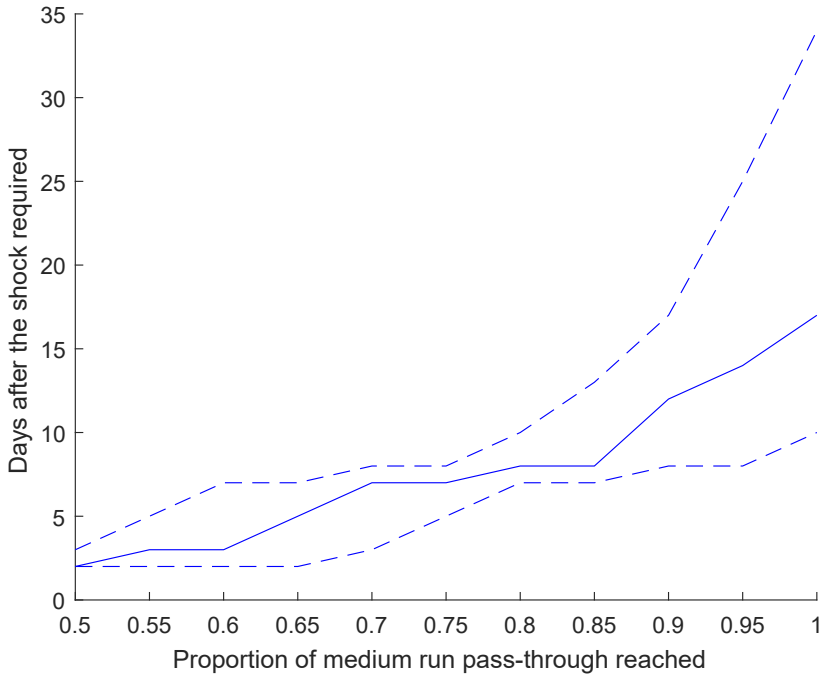
In Section 4.5 of the paper, we have argued that substitution towards higher quality of imported goods is very unlikely to occur within the relevant two weeks after the shock. For the interpretation of our measure of the speed of the ERPT, however, it is not enough to discard substitution effects within the first days after the shock. To see why, assume that there is substantial quality upgrading of Swiss imports after some month (our medium run). In that case, the estimated coefficients on our dummies of, say, April to June 2015 may be biased upward. Such biases may then lead us to underestimate the difference between the short-run and the medium-run pass-through and ultimately induce an erroneously early *end date*.[74] We claim, however, that the induced error affecting our definition of the end date is likely to be small. This claim is based on three grounds. First, the same substitution effect that affects unit values of imports invoiced in Swiss francs should affect imports invoiced in euro as well (see also section C.2, where we show that there is no separation of Swiss franc and euro invoicing along products lines). The fact that in the euro sample the ERPT is virtually one throughout all time horizons suggests that substitution effects are negligible in the euro sample and thus likely to be small in the Swiss franc sample. Second, when unit values of Swiss imports suffer from substitution effects towards higher qualities, then unit values of Swiss exports must suffer from substitution effects towards lower qualities. This observation implies that the inferred end date in the export sample should be biased upward. A comparison of the inferred end dates across both samples, however, reveals that there is no substantial difference between the end dates in the import and in the export sample. Third and finally, the background information presented in section 2 suggests that macroeconomic variables such as output, price level of the import basket, Swiss expenditures on imported goods, were surprisingly stable and thus do not suggest strong substitution effects were at play.

To provide additional information on the dynamics of the ERPT, Figure (17) depicts the number of days needed to achieve a certain portion of the medium-run pass-through. Confidence intervals are constructed by using our estimates of the dummy coefficients and their covariance to sample from a joint normal distribution. For each sample, we compute the number of days it takes for the accumulated pass-through to reach a fraction of the

[74] We note that the definition of the *start date* relies on a comparison of daily dummies and the pre-shock period and is thus unaffected by the potential bias.

medium-run pass-through. The figure shows the median of all samples and the 2.5^{th} and 97.5^{th} percentiles representing a 95% confidence interval.

Figure 17: Days required to reach proportions of medium-run pass-through for imports invoiced in CHF



Notes: confidence intervals from 10000 repetitions.

I Additional robustness checks

In this section, we present additional robustness checks. For the ease of the reader, Table 11 presents all robustness checks results in a single table, including those discussed in the main section of the paper.

Table 11: Daily regression results (specification 1) for CHF invoiced import transactions

Sample	Start day	End day	Start day PT	Med-run PT	Obs.
1) baseline	2 (1 2)	12 (8 17)	0.32 (.007)	0.61 (0.003)	8608997
2) sup. units.	2 (1 2)	9 (7 13.5)	0.38 (.012)	0.58 (.006)	2273988
3) big imp.	4 (1 8)	11 (4 19)	0.19 (.014)	0.37 (.009)	1479713
4) value $>$ 300	2 (1 3)	14 (8 22)	0.15 (.009)	0.41 (.005)	3306895
5) value $<$ 300	1 (1 2)	8 (7 12)	0.14 (.009)	0.72 (.004)	5164280
6) consump. Goods	2 (1 2)	7 (7 13)	0.49 (.008)	0.74 (.004)	4489617
7) invest. goods	2 (1 4)	11 (8 21)	0.13 (.011)	0.47 (.005)	4086878
8) interm. goods	2 (1 4)	12 (6 25)	0.29 (.014)	0.59 (.006)	1846694
9) diff. goods	2 (1 2)	8 (7 16)	0.30 (.007)	0.60 (.003)	7699880
10) ref. goods	2 (1 4)	9 (4 13)	0.27 (.019)	0.63 (.009)	614508
11) org. exchange	5 (1 7)	12 (1 20)	0.45 (.040)	0.92 (.026)	53824
12) single trans.	2 (1 2)	2 (2 7)	0.47 (.015)	0.51 (.006)	2165578
13) transp. by road	1 (1 2)	9 (8 16)	0.08 (.007)	0.63 (.003)	7788437
14) imp. from US	3 (1 3)	3 (3 3)	0.83 (.017)	1.13 (.009)	657769
15) high var. triplets	2 (1 4)	10 (5 17)	0.28 (.021)	0.72 (.009)	1993539
16) low var. triplets	2 (1 2)	8 (3 19)	0.22 (.007)	0.56 (.004)	1246369
17) high intrafirm (noga)	1 (1 3)	4 (2 9)	-0.25 (.022)	0.53 (.012)	521746
18) low intrafirm (noga)	2 (1 2)	7 (2 19)	0.53 (.014)	0.82 (.008)	1544136
19) high intrafirm (census)	3 (1 3)	9 (3 11)	0.35 (.)	0.57 (.)	580933
20) low intrafirm (census)	2 (1 2)	6 (2 13)	0.54 (.)	0.63 (.)	1391565
Exports (baseline)	2 (1 7)	11 (9 16)	0.03 (.009)	0.38 (.004)	5865536

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 represents the first day where 90% of the medium-run pass-through has been achieved. Standard errors or 95% bootstrap confidence intervals are shown in parenthesis. The baseline specification is the one described in Section 4.1. The following subsamples are used for each of the other specifications presented in this table: 2. augmented 8-digits HS code for which a precise unit of measure is available; 3. 8-digits HS code - postal code triplets which have the largest shares of total imports and whose collective share is larger than two-thirds; 4. transactions with value larger than CHF 300; 5. transactions with value smaller than CHF 300; 6. 8-digit HS codes classified as a consumption goods (OZD classification); 7. 8-digit HS codes classified as investment goods (OZD classification); 8. 8-digit HS codes classified as intermediate goods (BEC classification); 9. differentiated goods (Rauch (1999) classification); 10. Reference priced goods (Rauch (1999) classification); 11. Goods traded on an organised exchange (Rauch (1999) classification); 12. customs declarations with a single transaction; 13. transactions of goods transported by road; 14. imports from the United States; 15. triplets where unit value variance is in the top 25th percentile; 16. triplets where unit value variance is in the bottom 25th percentile; 17. HS goods that fall in NOGA codes where more than 75% of firms report being engaged in intrafirm trade in the data from Fischer, Lutz and Walti (2007) 18. HS goods that fall in NOGA codes where less than 25% of firms report being engaged in intrafirm trade in the data from Fischer, Lutz and Walti (2007); 19. NAICS for which U.S. imports from the Eurozone have a related party share higher than 75%. ; 20. NAICS for which U.S. imports from the Eurozone have a related party share lower than 25%.

I.1 Proxying firm size

The first set of our additional robustness checks addresses 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 the import prices of large, import-intensive firms exhibit a lower ERPT because a portion of their production costs varies with foreign inputs.[75] Equivalently, the speed of response to the shock may differ by firm size and import intensity.

Although we cannot control for firm characteristics, we nevertheless attempt 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-codes with the largest import values. This criterion constitutes only an approximate proxy for firm size, but it does exclude numerous small Swiss importers. The results, which are given in row 3 in Table 11, indicate that the speed of adjustment of 11 working days is also rapid for large importers.[76]

An additional method of proxying for firm size is to separate transactions of large value from transactions of low value.[77] We adopt the value of CHF 300 as a threshold to define similarly sized sub-samples of small-value shipments and of large-value shipments.[78] Restrictions 4 and 5 in Table 11 show that the medium-run pass-through into import unit values is lower for large shipments and higher for small ones. The estimations again show that no notable differences are observed for the start and end dates.

I.2 The role of distance

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. In particular, the proximity could drive rapid price adjustment, because delivery time is reduced to a minimum between neighboring economies and corresponding contracts may be written in the short term.

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

[76] In Appendix J, Figure 19 depicts the daily results for the imports of large importers.

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

[78] The 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 J, Figure 20 shows the daily results for the import unit values of transactions of less than CHF 300. Figure 21 shows the daily results for the import unit values of transactions of more than CHF 300.

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 particularly short delivery time, potentially driving the rapid reaction of prices. [79] The results are reported in Figure 28 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 6) and the pass-through starts on January 16 and reaches most of its medium-run level 8 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, because between January 2014 and 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 significant samples defined by invoicing currencies (Swiss franc, euro, and U.S. dollar), which further reduces the size of each individual sample.[80]

The results are reported in Figure 29 in Appendix J and summarized in row 14 in Table 11 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. The unit values of goods invoiced in U.S. dollars and euros react mechanically and instantaneously (see top and the middle panel of the figure). Importantly, the 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 appear to react promptly. This finding reported for imports from the United States suggests that swift price adjustment is not limited to geographically close trade partners.[81]

[79] 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.

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

[81] It may be conjectured that Swiss trade with the U.S. is less affected by intra-firm trade. We observe, however, that in our sample of U.S. imports, we estimated a higher pass-through than for euro area imports (medium term 1.12 for US and 0.6 for Europe). Neiman (2010) finds that intra-firm transactions have a higher pass-through. If imports from the euro area is more affected by intra-firm trade, we should expect a higher pass-

through for European transactions.

J Graphs for the robustness checks

J.1 Graphs for proxying firm size

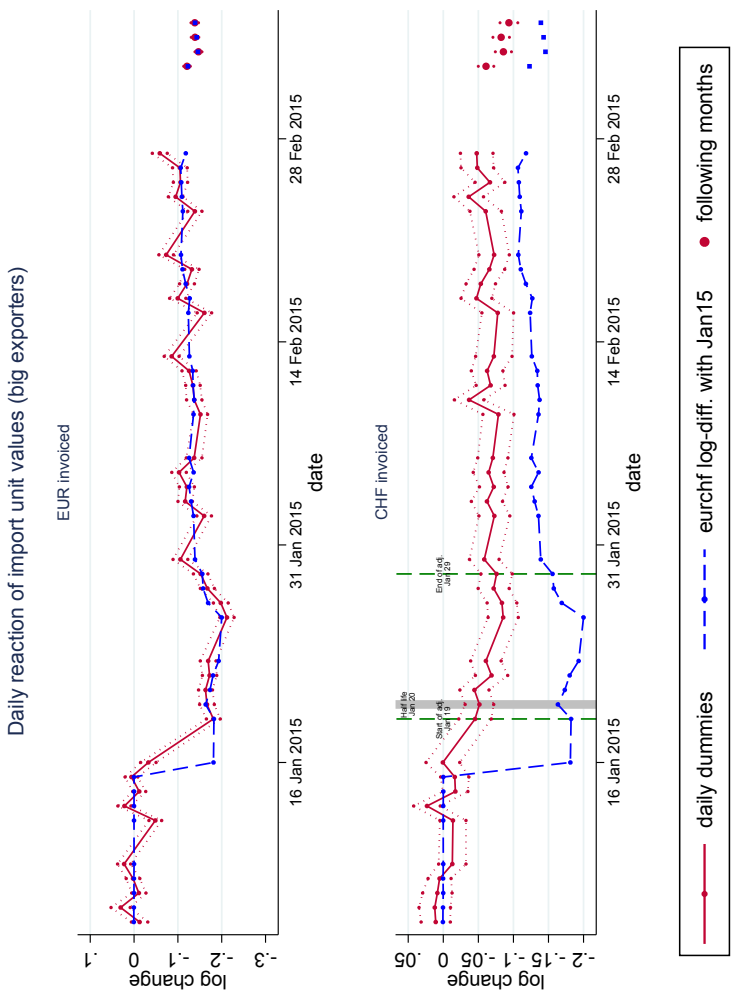


Figure 18: Daily dummies for import unit values from large HS-country export combinations (specification 1). The regression includes augmented HS-postal code-country triplet fixed-effects and a 2-digit HScountry-specific trend. Errors are clustered at the postal code level.

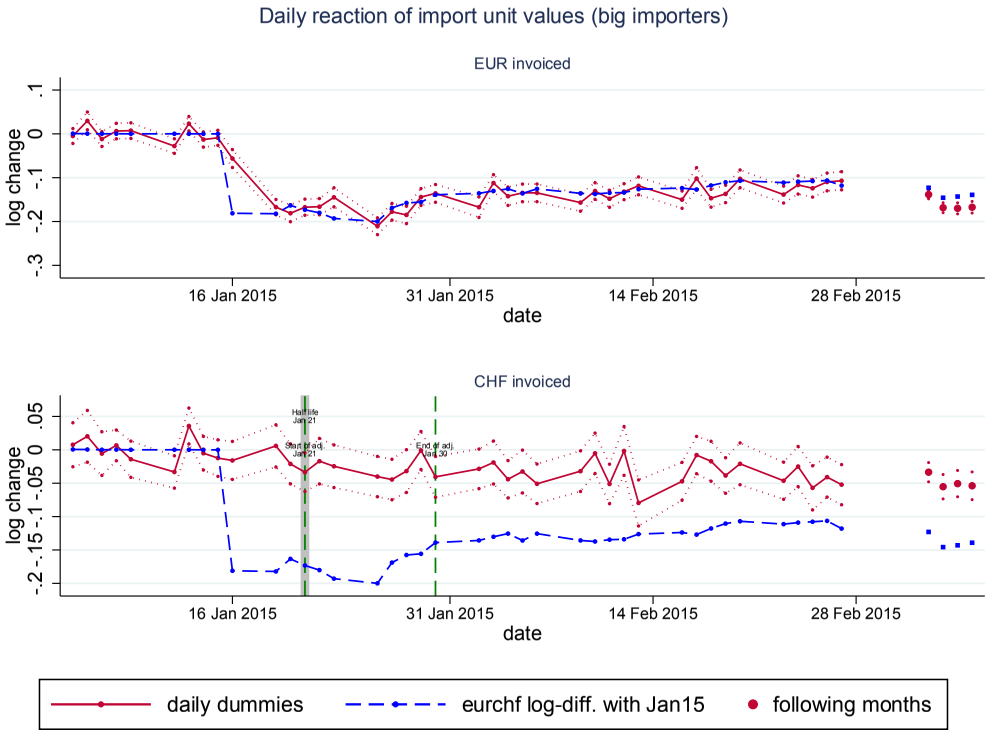


Figure 19: Daily dummies for import unit values of large HS-postal code importer combinations (specification 1). The regression includes augmented HS-postal code-country triplet fixed-effects and a 2-digit HS-country-specific trend. Errors are clustered at the postal code level.

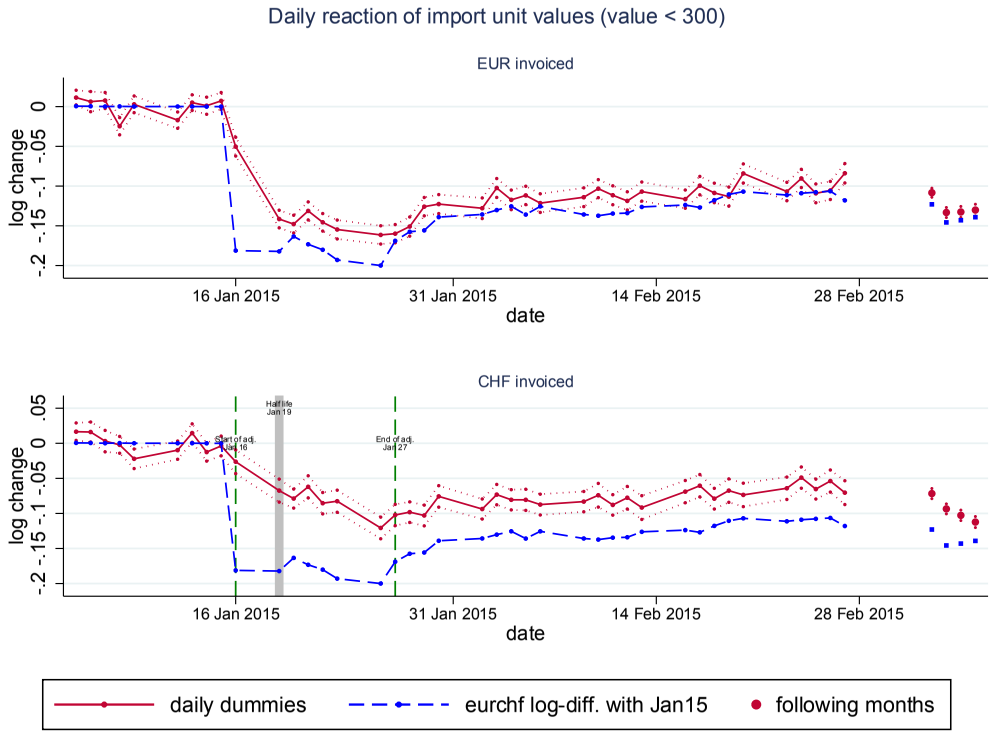


Figure 20: Daily dummies for import unit values for shipments worth less than CHF 300 (specification 1). The regression includes augmented HS-postal code-country triplet fixed-effects and a 2-digit HScountry-specific trend. Errors are clustered at the postal code level.

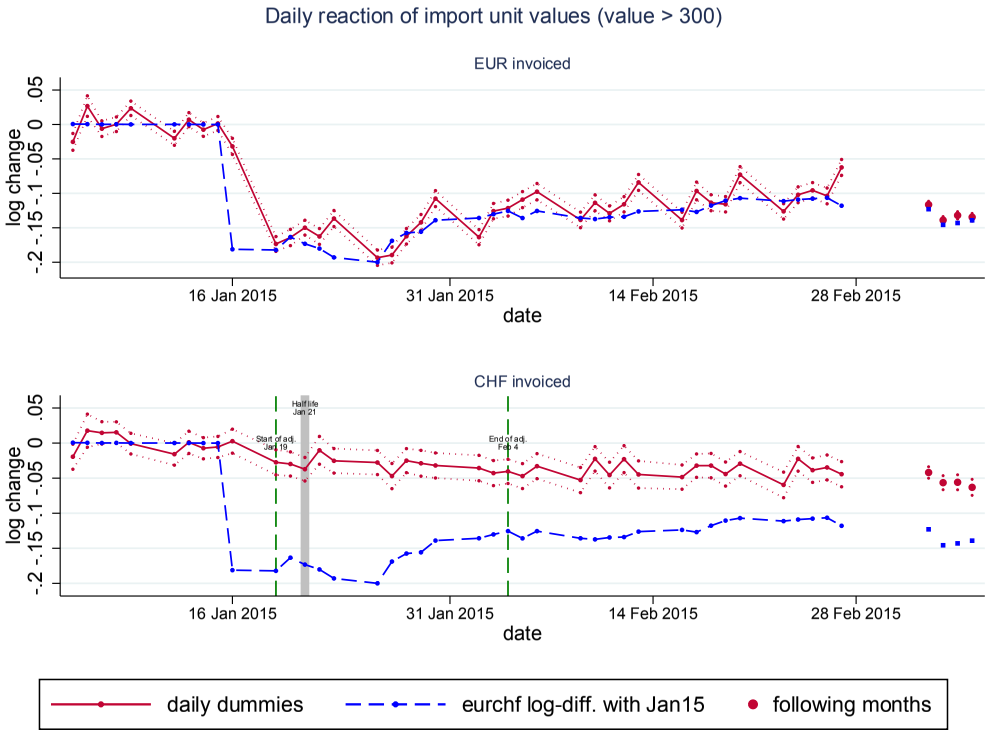


Figure 21: Daily dummies for import unit values for shipments worth more than CHF 300 (specification 1). The regression includes augmented HS-postal code-country triplet fixed-effects and a 2-digit HS-country-specific trend. Errors are clustered at the postal code level.

J.2 Graphs for intermediate, investment and consumption goods

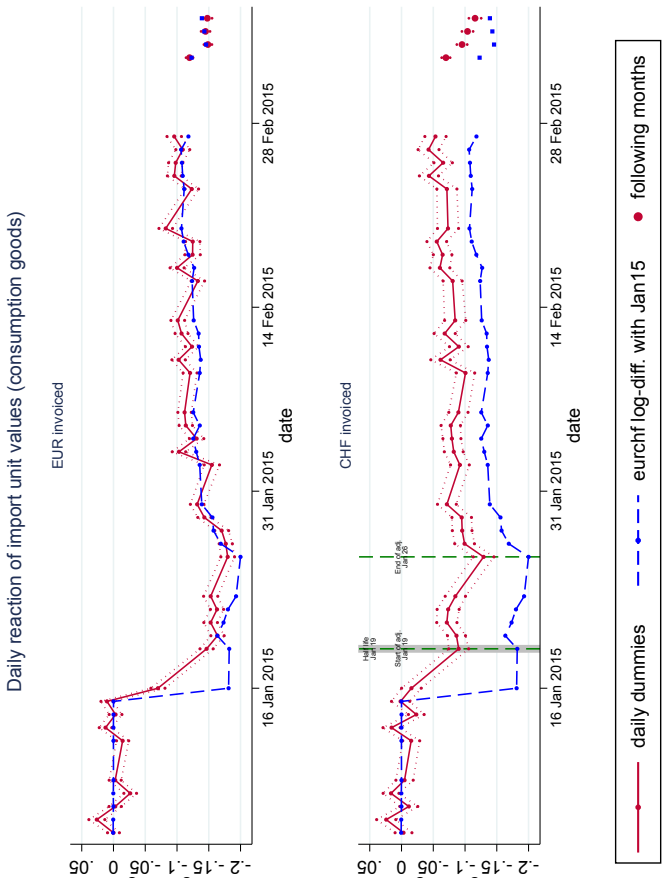


Figure 22: Daily dummies for import unit values for consumption goods (specification 1). The regression includes augmented HS-postal code-country triplet fixed-effects and a 2-digit HScountry-specific trend. Errors are clustered at the postal code level.

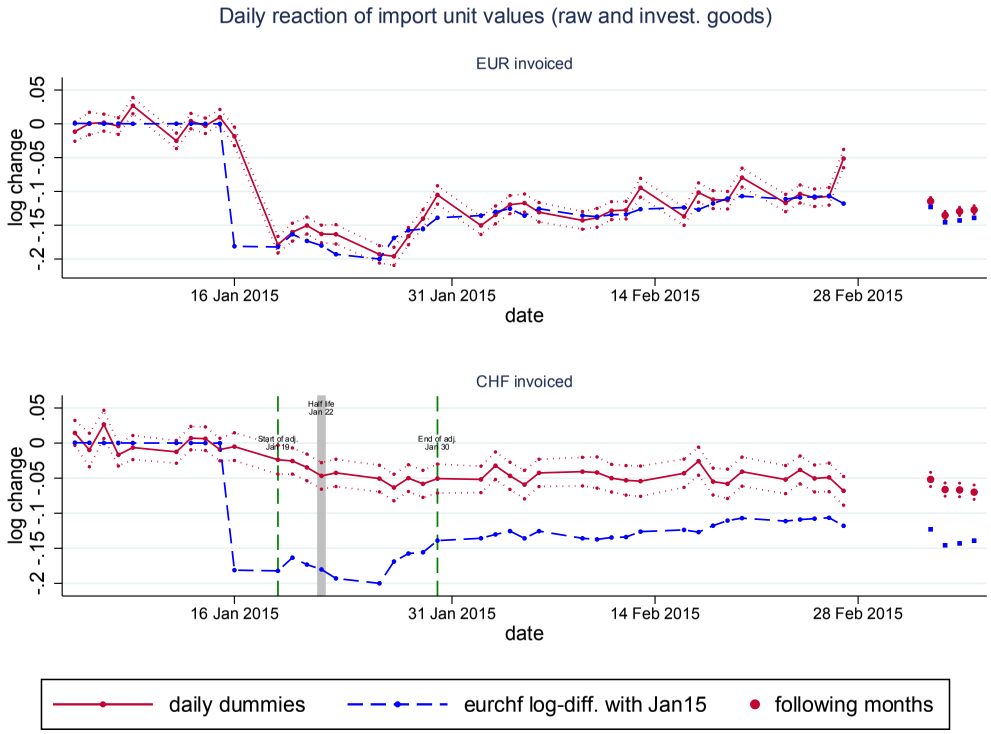


Figure 23: Daily dummies for import unit values for investment goods and raw materials (specification 1). The regression includes augmented HS-postal code-country triplet fixed-effects and a 2-digit HS-country-specific trend. Errors are clustered at the postal code level.

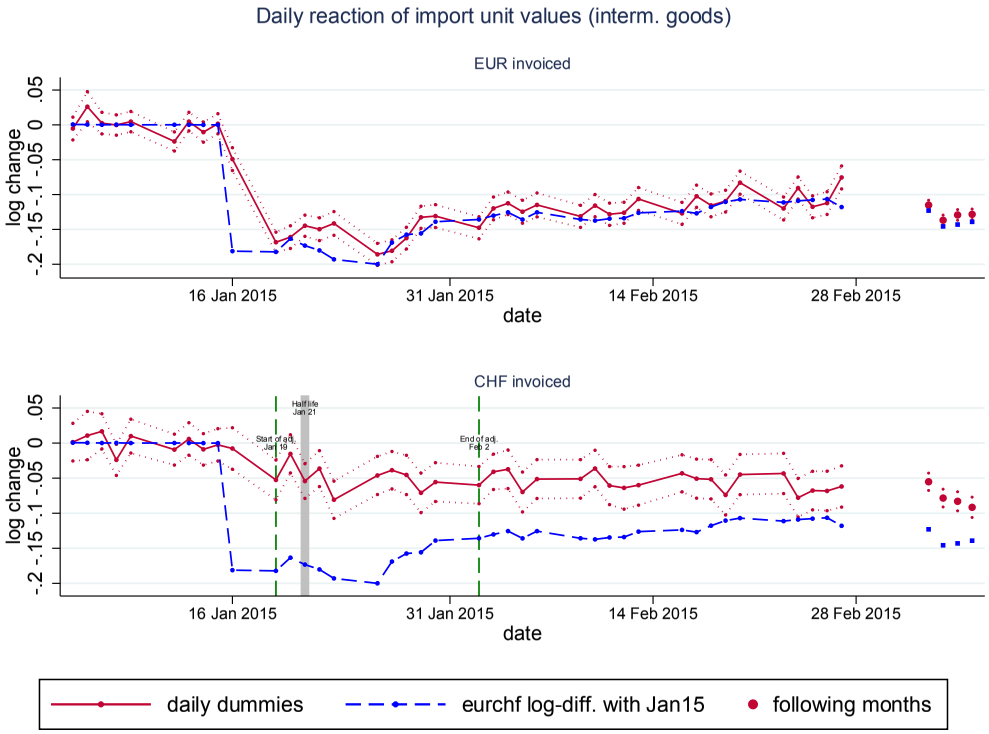


Figure 24: Daily dummies for import unit values for intermediate goods (specification 1). The regression includes augmented HS-postal code-country triplet fixed-effects and a 2-digit HS-country-specific trend. Errors are clustered at the postal code level.

J.3 Graphs by Rauch classification

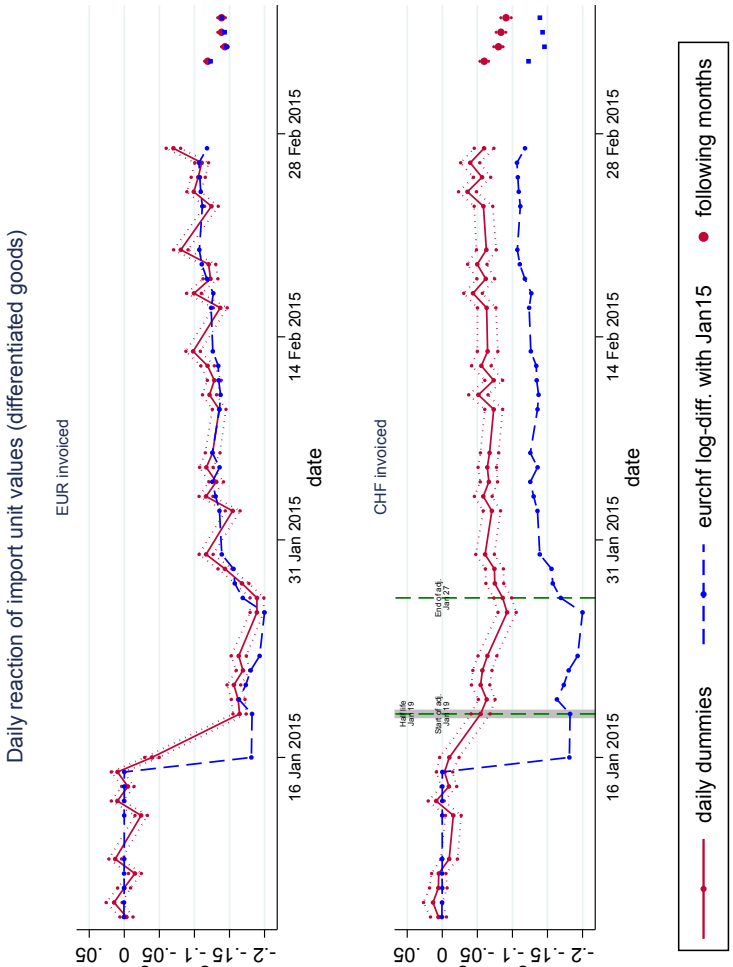


Figure 25: Daily dummies for import unit values of differentiated goods (specification 1). The regression includes augmented HS-postal code-country triplet fixed-effects and a 2-digit HScountry-specific trend. Errors are clustered at the postal code level.

J.4 Graphs for single item declarations

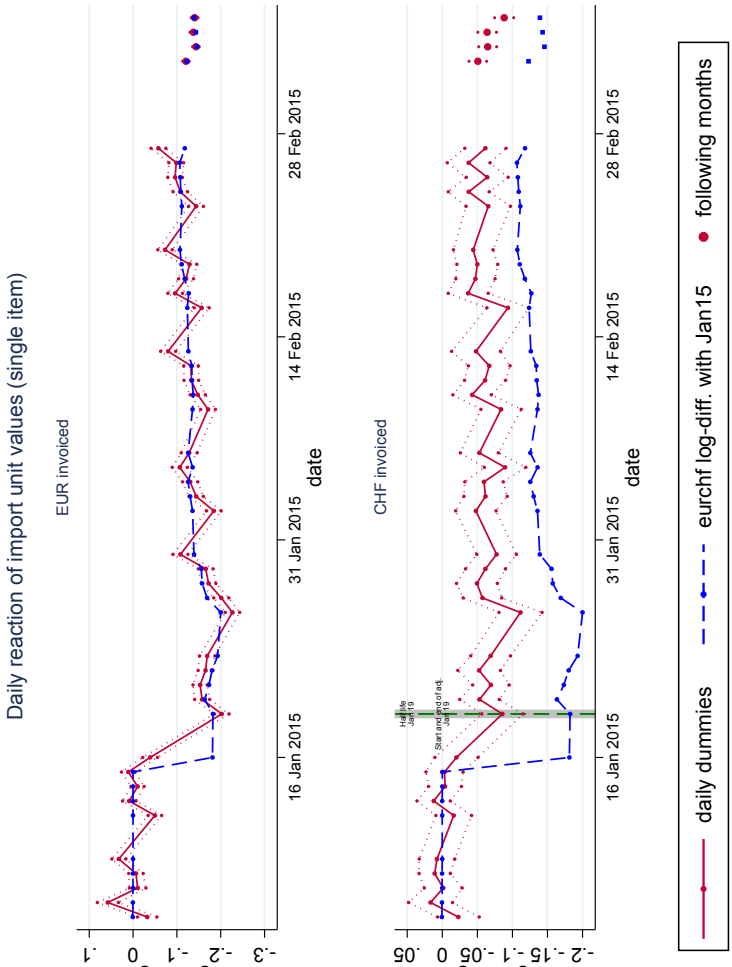


Figure 26: Daily dummies for import unit values when the transaction is unique in the custom declaration (specification 1). The regression includes augmented HS-postal code-country triplet fixed-effects and a 2-digit HS-country-specific trend. Errors are clustered at the postal code level.

J.5 Graphs for section-level regressions

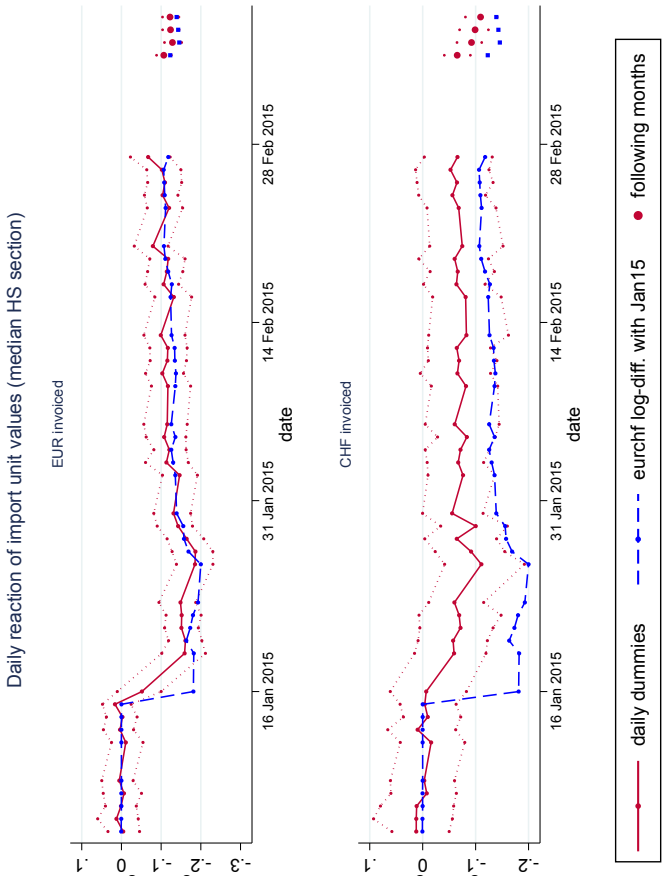


Figure 27: Median of each HS section specific daily coefficients on import unit values (specification 1). The regression includes augmented HS-postal code-country triplet fixed-effects and a country-specific trend. Errors are clustered at the postal code level.

J.6 Graphs for distance-related regressions

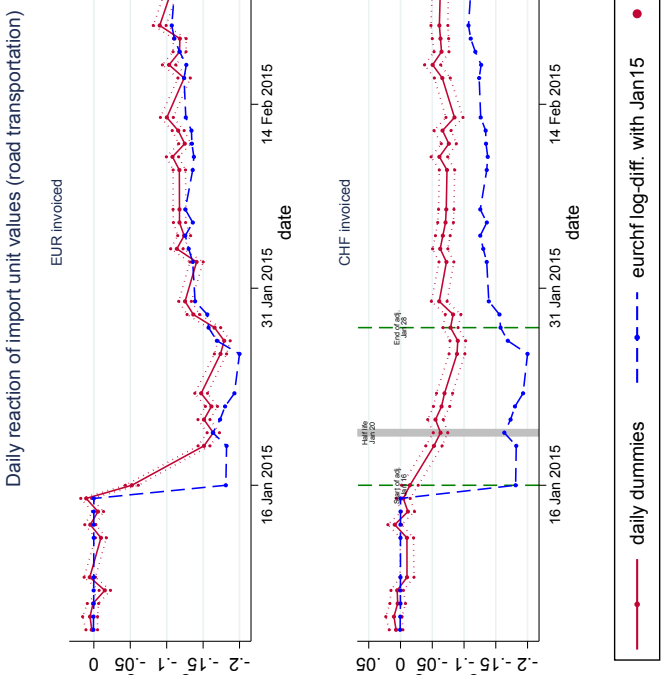
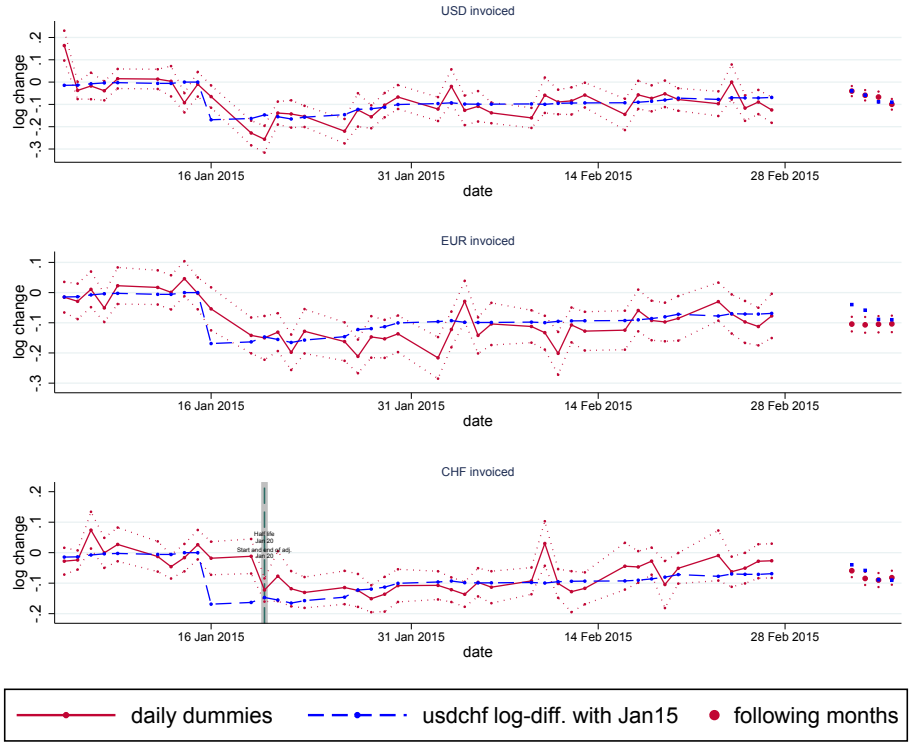


Figure 28: Daily dummies for import unit values (specification 1). The sample includes only imports transported via road. The regression includes augmented HS-postal code-country triplet fixed-effects and a 2-digit HS-country-specific trend. Errors are clustered at the postal code level.

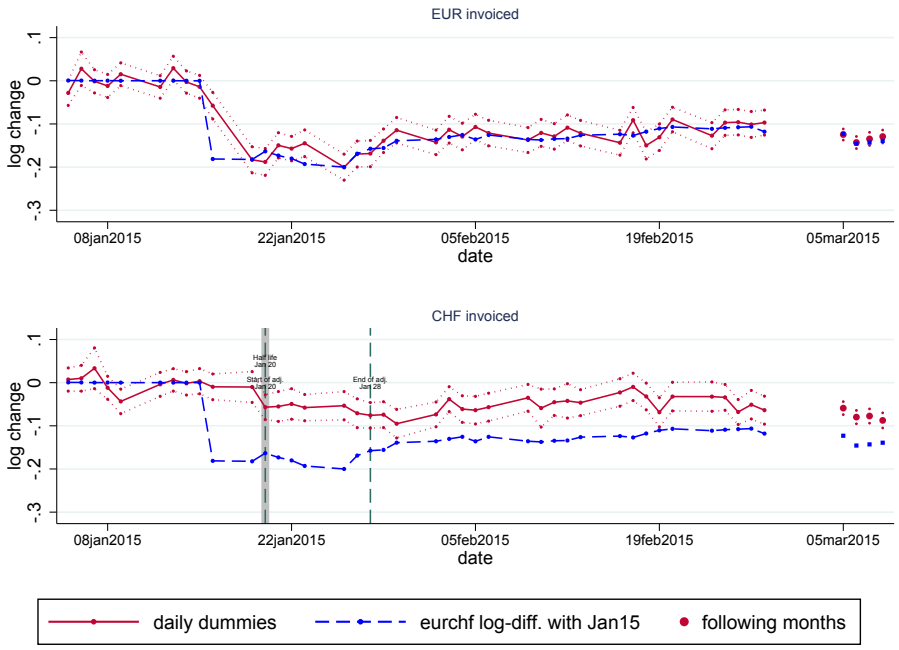
Figure 29: Daily reaction of import unit values - trade with the United States



Daily dummies for import unit values (specification 1). The sample includes only imports from the United States to Switzerland. The regression includes augmented HS-postal code-country triplet fixed-effects and a 2-digit HS-country-specific trend. Errors are clustered at the postal code level.

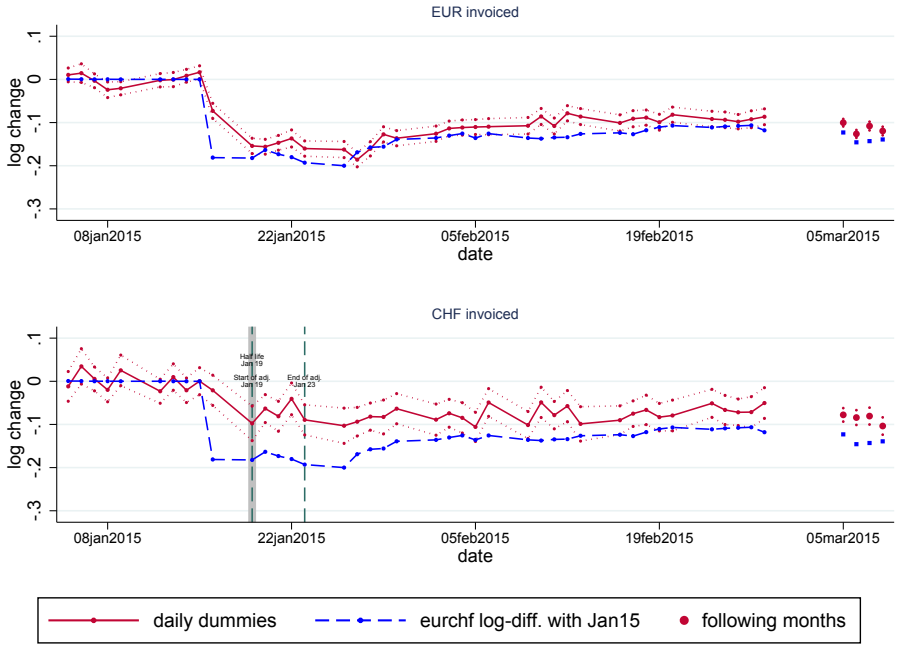
J.7 Graphs for intrafirm related regressions

Figure 30: Daily reaction of import unit values (high related-party transactions)



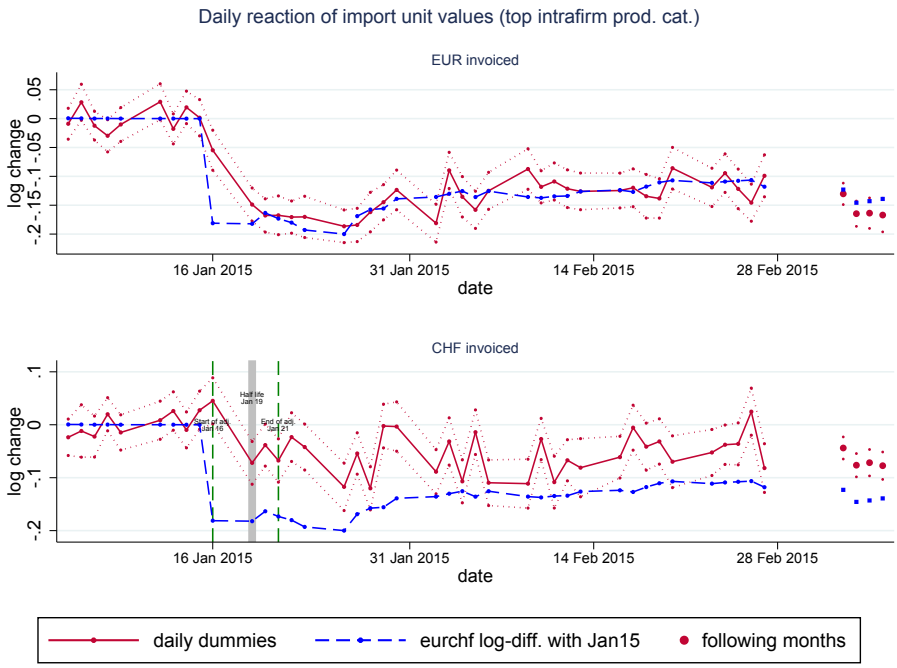
Daily dummies for import unit values (specification 1).The sample includes only HS codes that correspond to NAICS (North American Industry Classification System) for which U.S. imports have a related party share lower than 75%. The digit level of the NAICS code is 6. The regression includes augmented HS-postal code-country triplet fixed-effects and a 2-digit HS-country-specific trend. Errors are clustered at the postal code level. Source: United States Census Bureau

Figure 31: Daily reaction of import unit values (low related-party transactions)



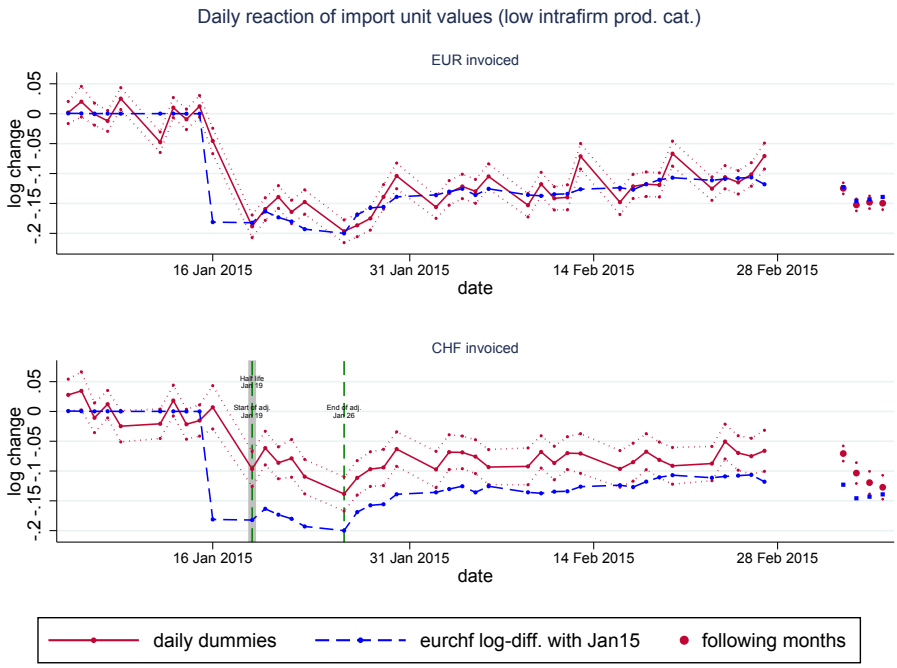
Daily dummies for import unit values (specification 1).The sample includes only HS codes that correspond to NAICS (North American Industry Classification System) for which U.S. imports have a related party share lower than 25%. The digit level of the NAICS code is 6. The regression includes augmented HS-postal code-country triplet fixed-effects and a 2-digit HS-country-specific trend. Errors are clustered at the postal code level. Source: United States Census Bureau

Figure 32: Daily reaction of import unit values (high intrafirm transactions)



Daily dummies for import unit values (specification 1).The sample includes only HS codes that correspond to NOGA codes (Swiss industry codes) that have intrafirm exports higher than 75%. The digit level of the NOGA code is 2. The regression includes augmented HS-postal code-country triplet fixed-effects and a 2-digit HS-country-specific trend. Errors are clustered at the postal code level. Source: Fischer et al. (2007)

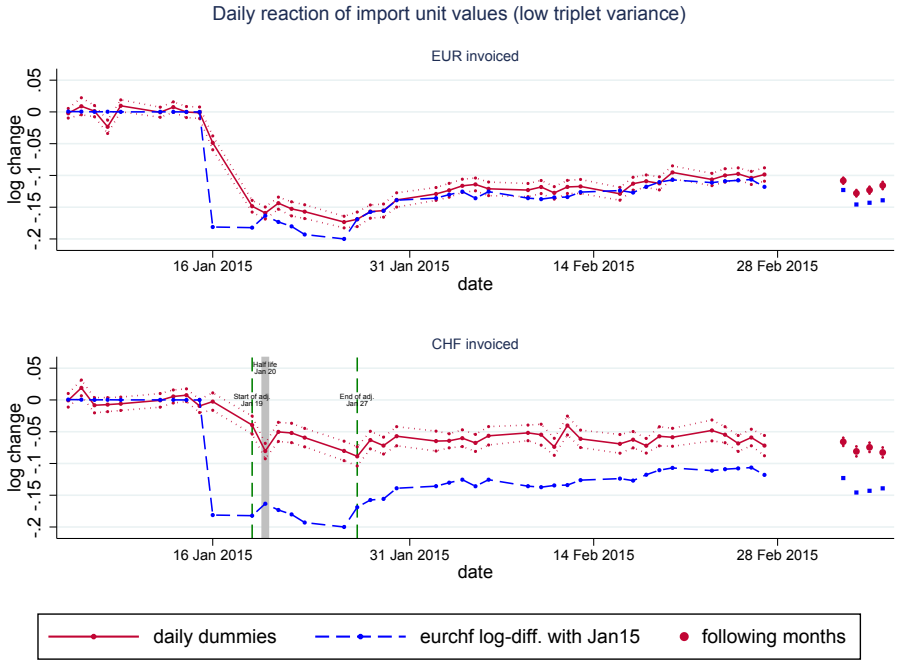
Figure 33: Daily reaction of import unit values (low intrafirm transactions)



Daily dummies for import unit values (specification 1).The sample includes only HS codes that correspond to NOGA codes (Swiss industry codes) that have intrafirm exports lower than 25%. The digit level of the NOGA code is 2. The regression includes augmented HS-postal code-country triplet fixed-effects and a 2-digit HS-country-specific trend. Errors are clustered at the postal code level. Source: Fischer et al. (2007)

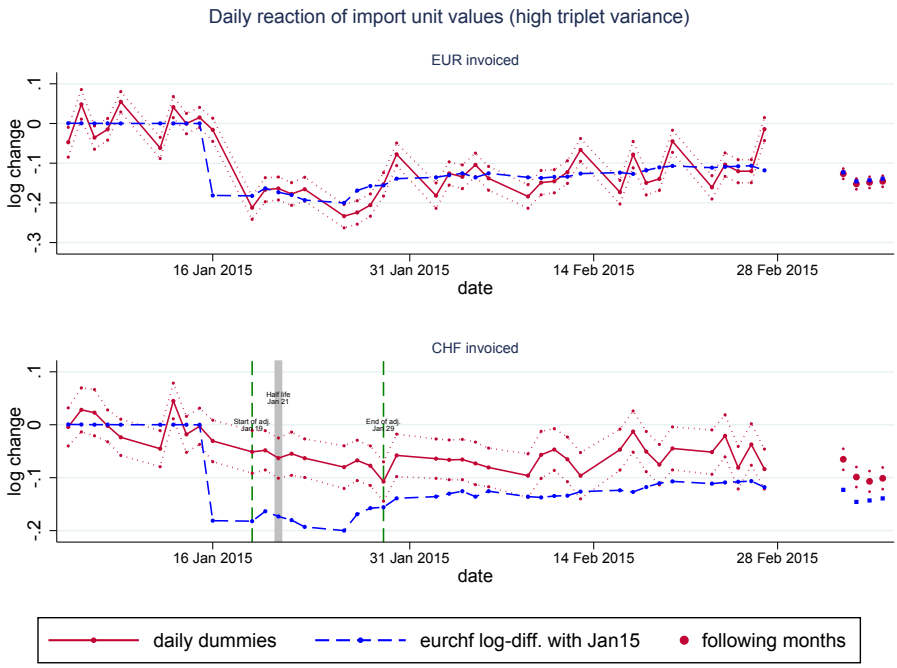
J.8 Graphs by within triplet variance

Figure 34: Daily reaction of import unit values (low within triplet variance)



Daily dummies for import unit values (specification 1).The sample includes only HS-country-postal code triplets whose 2014 within variance is in the bottom 25th percentile. The regression includes augmented HS-postal code-country triplet fixed-effects and a 2-digit HS-country-specific trend. Errors are clustered at the postal code level.

Figure 35: Daily reaction of import unit values (high within triplet variance)



Daily dummies for import unit values (specification 1).The sample includes only HS-country-postal code triplets whose 2014 within variance is in the top 25th percentile. The regression includes augmented HS-postal code-country triplet fixed-effects and a 2-digit HS-country-specific trend. Errors are clustered at the postal code level.

K 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 suggest 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, because the exchange rate and prices should be jointly determined. Although this violation is usually rejected because exchange rates and prices are not found to be cointegrated (see, e.g., Campa and Goldberg (2005)), other sources of endogeneity exist and imperfect measurements 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) suggest 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 simultaneous innovations in exchange rates and producers' costs. 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) adopt a different approach by stressing the asset-price nature of exchange rates. The authors suggest that exchange rates depend on the expectations of future fundamentals, adding that innovations in 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 affects the exchange rate at time t, and producers' costs 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 $\hat{l} > 0$.[82]

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 find that $plim\frac{Z'u}{T} = 0$, such that the direction of the asymptotic bias only depends on the behavior of A and $e'u$.

When 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 $\eta_{\hat{l}}$. In addition, if the error terms are autocorrelated[83], 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 $l > 0$ such that all estimates on lags "further away" than $\hat{l}$ are inconsistent. The direction of the bias then depends on $\eta_{\hat{l}}$ and on ρ.

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

[82] If the marginal cost is measured with an error (e.g., proxied using expenditure shares and the 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. Another example is a shock in preferences in the demand for an exporter's good, which would have a similarly uncontrolled effect on both the price and the exchange rate.

[83] 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.

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

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

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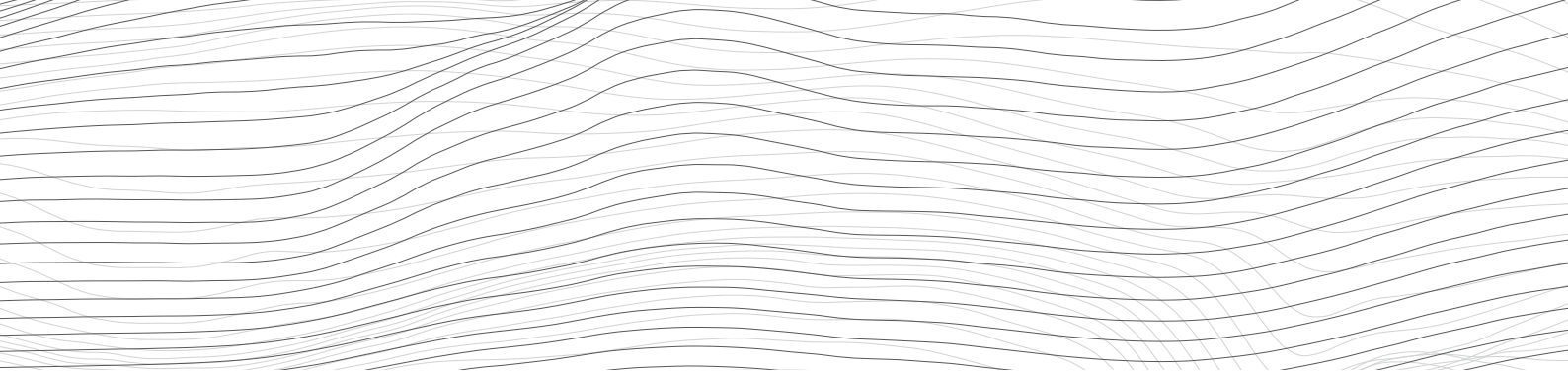

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