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Abnormal pricing in international commodity trade: Empirical evidence from Switzerland

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ABSTRACT

Mispricing of international trade in natural resources poses a significant risk for tax base erosion from resource-rich, developing countries, while also contributing to regulatory and financial risks for commodity trading hubs. This paper presents a novel empirical approach which combines statistical price-filter analysis methods with commodity market research to provide evidence on the magnitude of abnormally priced Swiss commodity imports. Our analysis compares transaction-level import prices to an arm's length price range representing fair market value and defined using contemporaneous benchmark prices from commodity exchanges, adjusted for product-specific factors. We find a significant magnitude of abnormally under-valued unwrought gold doré imports as well as relatively smaller magnitudes of abnormally under-valued cocoa and coffee imports. Next, we contrast our new estimates with traditionally used proxies for trade mispricing based on aggregate mirror trade statistics to highlight the unreliability of widely used methods and data sources. Finally, we discuss the limitations in our analysis even using the best available administrative data which reinforces the urgency to improve the statistical infrastructure used to record international commodity trading in order to promote transparency and improve international trade governance.

1. Introduction

Mispricing of international trade in natural resources is a global challenge for both developing and advanced countries (J. Bhagwati and Hansen, 1973; J. N. Bhagwati et al., 1974; Fisman et al., 2008; Fisman and Wei, 2004; Ndikumana et al., 2015; Ndikumana and Sarr, 2019). Resource-rich developing countries generate a significant share of their public revenues from the production and sale of mineral and agricultural commodities. Effective revenue generation from the natural resource sector is critically important for meeting domestic revenue mobilization goals in developing countries which comprise 63 of the top 70 mining countries by contribution of the sector to the economy (International Council on Mining and Metals, 2014; Readhead, 2018; Venables, 2016).[1] There is also an increased focus on promoting revenue generation through high-value agricultural commodity production and exports reflected in the growing share of horticultural, processed, and semi-processed agricultural commodities in total agricultural exports from developing countries (Fukase and Martin, 2017). Similarly, the commodity-trading sector accounts for a significant share of economic activity in leading trade hubs.[2] These trading hubs accordingly face significant risks from illicit financial inflows that expose their trading and financial sectors to legal and financial risks from tax evasion, money laundering and stolen assets, as well as criminal or terrorism financing (Financial Action Task Force, 2016a).

The existing literature has identified two primary channels for commercial actors to transfer financial capital across national

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[1] According to the International Monetary Fund's (IMF) research on ten mineral-rich countries, mining's share of total government revenue was 11% on average, with a maximum of 40% for Botswana.

[2] As per the Swiss Trading and Shipping Association, the commodity trading sector accounts for approximately 4% of Switzerland's GDP and contributes significant shares of public revenue to the cantons of Geneva (22%), Lugano (69%) and Zug (10%). Source: https://stsa.swiss/knowledge/switzerland (Accessed: March 2020).

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Table 1
Summary statistics of selected commodities.

HS Code: 7108.12		Gold: Non-monetary, Other unwrought forms			
	Observations	Mean	Std. Dev.	Maximum	Minimum
Quantity (kg)	55,986	273.0	775.5	13,764	0.00100
Value (CHF)	55,986	8,625,000	24,730,000	507,300,000	1
Unit Price (CHF/kg)	55,986	39,263	906,764	203,500,000	0.0614
HS Code: 7403.11		**Refined copper: Cathodes and sections of cathodes**			
	Observations	**Mean**	**Std. Dev.**	**Maximum**	**Minimum**
Quantity (kg)	359	12,095	11,992	31,460	0.0900
Value (CHF)	359	83,112	79,008	242,194	80
Unit Price (CHF/kg)	359	651.4	1811	15,320	1.501
HS Code: 1801.00		**Cocoa beans, whole or broken, raw or roasted**			
	Observations	**Mean**	**Std. Dev.**	**Maximum**	**Minimum**
Quantity (kg)	13,121	22,190	21,693	246,875	0.0600
Value (CHF)	13,121	70,467	66,876	780,975	1
Unit Price (CHF/kg)	13,121	10.89	34.55	2990	0.172
HS Code: 901.11		**Coffee, not roasted, not decaffeinated**			
	Observations	**Mean**	**Std. Dev.**	**Maximum**	**Minimum**
Quantity (kg)	38,483	24,252	23,920	289,800	0.0440
Value (CHF)	38,483	102,892	103,471	1,890,000	1
Unit Price (CHF/kg)	38,483	6.171	30.91	5227	0.0783
HS Code: 901.12		**Coffee, not roasted, decaffeinated**			
	Observations	**Mean**	**Std. Dev.**	**Maximum**	**Minimum**
Quantity (kg)	3890	18,136	10,110	60,000	0.165
Value (CHF)	3890	101,764	63,944	334,208	2
Unit Price (CHF/kg)	3890	8.859	40.38	2098	0.0968

Note: Swiss Federal Customs Administration List of Tariff Headings document available here: https://www.ezv.admin.ch/ezv/en/home/information-companies/customs-tariff—tares.html (accessed: February 2018).

boundaries: trade mispricing and intra-firm transactions of multinational firms, i.e. transfer pricing.[3] Trade mispricing is defined as a form of customs and/or tax fraud involving exporters and importers deliberately misreporting the value, quantity, source, destination, or nature of goods or services in a commercial transaction. The economic motives include tax-motivated profit shifting and evasion of customs duties or trade restrictions on particular commodities or countries (Bhagwati and Hansen, 1973; Fisman and others, 2008; Fisman and Wei, 2004, 2009; Mishra and others, 2007; Vézina, 2015). Developing countries often lack the tax administration and customs valuation capacity to monitor complex tax avoidance techniques used by multinational enterprises (MNEs). Mispricing of commodities exported and transferred to related parties is therefore one of the main transfer pricing risks related to international commodity trade (Bernard and others, 2006; Clausing, 2003; Cristea and Nguyen, 2016; Readhead, 2018; Beer and others, 2018).

Available statistical evidence on measurement of trade mispricing is generally limited to macroeconomic studies of partner-country trade gaps or asymmetries in aggregate export and import statistics of trading partners (Bhagwati and others, 1974; Fisman and Wei, 2004; Global Financial Integrity, 2017; Kellenberg and Levinson, 2018; Ndikumana, 2016; Vézina, 2015). The methodologies used in these studies have some important limitations due to which their large estimates of trade mispricing are generally considered weak evidence of cross-border financial flows. Some studies have used transaction-level international trade statistics to analyze trends of abnormal pricing at the product-level; however this evidence generally remains limited due to administrative restrictions on access to transaction-level Customs data (Bernard et al., 2006; Clausing, 2003; Cristea and Nguyen, 2016; Hong and others, 2014; Hong and Pak, 2017; Vicard, 2015; Zdanowicz and others, 1999).

In this paper, we use transaction-level trade statistics from Switzerland to develop an innovative empirical approach to estimate the magnitude of abnormal pricing for imports of four major commodities, including gold, copper, coffee and cocoa beans. These commodities represent the largest metallic and agricultural products traded by Swiss commodity trading firms measured by total value and volumes. Abnormal pricing is defined as the magnitude of trade valued outside an assumed arm's length price range which represents fair market value between unrelated buyers and sellers and is considered a reliable indicator for trade mispricing risks (Hong and Pak, 2017; World Customs Organization, 2018). We compare the unit values (CHF per kilogram) of transaction-level trade microdata with an appropriate market benchmark calculated using free-market prices adjusted for relevant product and market-specific factors identified by traders and regulators. This methodology is motivated by the World Trade Organization's Transaction Value methods for customs valuation, and the Comparable Uncontrolled Price (CUP) method for transfer pricing analysis of trade between related firms (Platform for Collaboration on Tax, 2017; United Nations, 2017).[4] These methods recommend the use of quoted, free-market prices as a starting point for identifying arm's length prices,

[3] This paper focuses on IFFs resulting from business and financial practices of legally established business entities involved in international trade, as opposed to the illegal cross-border activities of criminal groups which may include smuggling and money laundering. There is an important, ongoing debate regarding whether intra-firm financial practices used to shift capital between different legal jurisdictions should be included in the definition for IFFs. We address this debate over concepts and definitions in Musselli and Bürgi Bonanomi (2020) and Carbonnier and Mehrotra (2018).

[4] The use of prices from commodities exchanges for transfer pricing analysis is also referred to as the 'sixth method' in some countries. This is distinct from Comparable Uncontrolled Prices (CUP) method which relies on data from comparable transactions between related and unrelated parties. See Section 2.4.2, United Nations (2017) for a detailed discussion of the 'sixth method.'

subject to reasonable comparability adjustments.[5]

Accordingly, we define the arm's length price range for our selected commodities based on their benchmark prices quoted by commodities exchanges, product characteristics and transportation costs driving normal variation in observed prices. For example, in the case of gold we use mine-level data sources on the purity of gold in doré bar production to calculate appropriate benchmark prices.[6] Estimates of transportation costs are provided during interviews with commodity traders. Under-valued imports are interpreted as evidence of illicit inflows of financial capital into the importing country. On the other hand, over-valued imports are interpreted as evidence of illicit financial outflows whereby financial capital leaves the importing country through the trade channel.

Next, our analysis considers commodities which are significantly heterogeneous and traded without reference to a commonly acknowledged benchmark price from a commodities exchange. In this case, we estimate abnormal pricing using endogenously calculated interquartile range (IQR) price filters. This method assumes that the price range between the 25th and 75th percentile of observed prices represents an arm's length price range. The OECD Transfer Pricing Guidelines allow for the use of interquartile range or other percentiles to help enhance the reliability of any transfer pricing analysis (paragraph 3.57, OECD, 2017). To operationalize this method, we calculate the interquartile range of unit prices by product, source and year, i.e. for all Swiss import transactions of a particular commodity from a source country in a given year. All transactions valued in the top and bottom quartiles of this price distribution are designated to be abnormally priced. We interpret these estimates as reliable indicators of trade mispricing risk which can assist revenue authorities to identify cases for detailed audit (Zdanowicz and others, 1999; Pak and others, 2003; De Boyrie and others, 2005; Hong and Pak, 2017).[7]

Finally, the price-filter estimates are compared to the asymmetries observed in aggregate, product-level data to contrast the micro-evidence with the more commonly used aggregate empirical methodologies, or partner-country trade gaps. According to this method, which relies on the principle of mirror statistics or double counting in international trade data, the reported trade values of the developed or industrialized trading partner are used as the arm's length value for the trade statistics of the developing country trading partner. We specifically test whether the results are consistent across methodologies. Our analysis is based on transaction-level imports data from Swiss Federal Customs Administration on two extractive (gold and copper) and two agricultural commodities (coffee and cocoa beans) for the period 2011–17. Meanwhile, the aggregate trade-gap analysis is based on product-level annual exports and imports data from the United Nations (UN) COMTRADE database.

Our main findings are as follows. *First*, we observe economically significant estimates of abnormal pricing in unwrought gold doré imports, i.e. semi-processed bars of gold and silver produced by mining companies after processing the raw ore. We define the arm's length price range for gold doré imports as follows: daily spot prices for refined gold and silver from the London Bullion Market Association (LBMA) are combined with country-level measures of purity of gold and silver in doré production derived from Metals Focus Gold-Silver Dore Database. This allows us to calculate daily benchmark prices for doré imports with varying levels of gold and silver content in doré between 2.8% and 95% by weight, depending upon the import source.[8] Next, we conservatively assume a 5% variation around these daily, country-level price benchmarks to account for variation in production, insurance and transportation, and refining costs to calculate the upper and lower bounds of the arm's length price range (Swiss Trading and Shipping Association, personal communication, June 2018). Comparing individual transaction level values with the arm's length price range indicates that CHF 21.7 billion of undervalued gold imports between 2011 and 17 (4.5% of total imports). The corresponding estimation of overvalued imports is negligible, equal to CHF 18.3 million for the same time period.[9]

Second, we note that the reliability of free market price filter methods is severely limited due to significant product heterogeneity which leads to the absence of an internationally recognized market reference price. Coffee and cocoa bean exports from different geographic regions, even within the same country, are traded at significantly different price levels, reflecting differences in bean varieties, quality, production and transportation costs. As a result, we are limited to using interquartile range price filter estimates of abnormal pricing for cocoa and coffee imports. We calculate the interquartile range by product, source country and year, i.e. for all Swiss import transactions of a particular commodity from a source country in a given year.

Our resulting estimates indicate minor magnitudes of abnormally under-valued imports, equal to CHF 44.7 million for cocoa beans (5% of total import value) and CHF 128.9 million for coffee beans (3% of total import value) between 2011 and 17. Since this methodology endogenously defines certain proportion of commodities to be abnormally priced by definition, we primarily use these results to identify trade mispricing risks in terms of the main trading partners whose exports to Switzerland are significantly and consistently under-valued. Therefore, these estimates are treated as risk indicators to help regulators focus limited audit resources on specific markets and actors. Overall, we conclude that the phenomenon of abnormally under-valued imports is relatively minor, but not economically insignificant, in agricultural commodities. For cocoa imports, we identify Ghana, Ecuador, Germany and Dominican Republic as the main trading partners whose exports to Switzerland demonstrate the largest magnitudes of abnormal pricing. Meanwhile for coffee imports, our analysis identifies Brazil, Colombia, Ethiopia, Guatemala and India as the main sources of trade mispricing risks. Finally, we also observe small magnitudes of over-valued coffee and cocoa bean imports to Switzerland, equal to 1% of imports for cocoa and 2% of imports for coffee between 2011 and 17. These over-valued imports can be explained by domestic Swiss demand for high-quality or premium quality inputs for consumption and production of luxury consumer food products (Swiss Trading and Shipping Association, personal communication, June 2018).

Finally, we compare our price filter estimates with partner-country

[5] Our empirical approach is distinct from comprehensive case-by-case audits which are based on accurately delineating each transaction based on a fact-intensive transactional and functional analysis on a case-by-case basis. Case-specific transactional and functional analysis may include the specific contractual terms of the individual transaction; the functions performed by each of the parties to the transaction, their account assets used and risks assumed; the individual characteristics of the transacted good; the specific market conditions in which the parties operate, including their relative competitive position; and the business strategies pursued by the parties, etc. For the list of criteria used to delineate the economically relevant characteristics for transfer pricing analysis, see: Chapter 1-D1, OECD (2017).

[6] Unwrought gold doré bars produced at the mine-level includes silver in the amalgam which is also taken into account for our analysis.

[7] Since the IQR is calculated endogenously using the observed distribution of export prices, this method directly assumes the presence of under and over-valuation in the trade statistics. However, the resulting estimates provide useful insights from a risk analysis perspective by identifying exporters and trade partners who consistently appear in the extreme tails of the products' observed price distribution.

[8] In the case of gold exporters to Switzerland who do not produce any gold domestically, we conservatively use as benchmarks the global maximum and minimum purity levels of gold and silver in doré.

[9] The product category for unwrought gold imports may also include transactions of small gold ornaments shipped to Swiss refineries for gold extraction. To account for these small shipments, we exclude 2854 transactions (5% of total transactions) of non-industrial amounts, defined as less than 1 kg by weight. However, this does not have any material impact on our estimates of abnormally valued gold imports.

trade gaps using mirror statistics from Switzerland and its trading partners. The annual product-level data highlights the presence of large asymmetries in reported Swiss imports of the selected commodities versus the exports to Switzerland reported by the rest of the world. These annual trade gaps are systematically positive for gold, cocoa, and coffee indicating that reported Swiss imports exceed what the rest of the world reports as exports to Switzerland. We hypothesize that these differences are driven by the entrepot trade effect in international trade statistics, whereby the exporting countries record their exports destination as the intermediate shipping hub from where commodities are then re-shipped or re-exported to Switzerland. However, Swiss Customs records the original source country as the trading partner leading to significant divergence in both trading partners' mirror trade statistics.

However, it is interesting to note that these trade gaps are systematically negative for copper indicating the opposite phenomenon. We hypothesize that a '*Switzerland effect*' exists in international trade statistics of copper driven by the merchanting activities of Swiss-based trading firms. The exporters record Switzerland as the destination for their copper exports in their trade statistics since they are selling to Swiss trading firms, however these firms store and trade the commodity to a third country instead of importing the physical commodities into Switzerland. These hypotheses are partially supported by the findings of other researchers using Customs data from producer countries, especially in the case of Zambian copper exports (Brulhart and others 2015).[10]

In conclusion, it is important to note some limitations of the trade micro-data used in our analysis. Swiss customs data does not record details regarding the quality and type of each commodity transaction, for example: purity of gold and copper, types of coffee and cocoa beans. This is consistent with the global harmonized system for product classification used in trade statistics which also does not distinguish between different sub-types of commodities. Furthermore, Swiss Customs does not record whether each transaction occurs between related or unrelated firms to determine transfer pricing risk from within-firm transactions. Therefore, any legal determination of customs fraud or abusive transfer pricing cannot be directly inferred from our aggregate statistical analysis. However, our evidence can help identify sources of such risk for a more detailed, administrative audit into the pricing practices of specific actors engaged in abnormally priced commodity trade.

Our findings aim to contribute to ongoing academic research and policy debates focusing on trade-based illicit financial flows, especially through commodity trading. Illicit financial flows (IFFs) from low-income and resource-rich countries have emerged prominently in contemporary debates regarding the 2030 Agenda for Sustainable Development (OECD, 2014; Reuter, 2012; United Nations, 2015). IFFs are broadly defined as cross-border financial flows that are illicit in their origin, method of transfer or eventual utilization. Accordingly, this phenomenon includes misinvoicing of international trade (customs fraud and tariff evasion), capital flight (violation of capital controls), international money laundering and tax evasion (proceeds from criminal activity), as well as aggressive tax avoidance by multinational firms and high net-worth individuals (Carbonnier and Mehrotra, 2018; Forstater, 2018). This flight of financial capital contributes to concerns regarding tax base erosion that constrain source countries' capacity to mobilize domestic financial resources to finance the 2030 Agenda for Sustainable Development. Current evidence indicates that tax revenues as a proportion of economic activity remain significantly lower across developing countries on average, compared to advanced economies.[11] Weak enforcement capacity and informality have been analyzed as leading drivers of the low tax base, however the role of IFFs remains under-analyzed due to an absence of robust data and empirical research methods to estimate its magnitude and prominent channels. This status quo disproportionately damages developing countries given their ongoing challenge to build well-functioning institutions and limited revenue sources to fund essential social services (Besley and Persson, 2014; Boyce and Ndikumana, 2001; Collin, 2020; Gordon and Li, 2009; Serieux, 2011).

2. Background: swiss commodity trading sector

We focus on Switzerland given its status as one of the world's largest commodity trading and financial hubs. Eggert and others (2017) used data from the Swiss Trading and Shipping Association to identify 496 firms with core interests in commodity trading or related activities concentrated in three regions: the Lake Geneva region (Geneva and Vaud), central Switzerland (Zug), and Lugano (Ticino). According to the STSA, the sector employs over 13,000 people directly and generates a further 20,000 jobs indirectly in Switzerland. The estimated share of global trade in major commodities handled by Swiss firms includes: 35% of Cocoa, 60% of Metals, 35% of Oil, 60% of Grains, 50% of Sugar, and 50% of Coffee.[12] A reconciliation of production, trade, and consumption data on sixteen major energy, extractive, and agricultural commodities by Jungbluth and Meili (2018) also corroborates that Swiss trading companies manage between 20 and 65% of global trade depending upon the commodity.

Switzerland is also an important precious metals processing hub due to the presence of four large precious metal refineries accredited by the London Bullion Market Association's Good Delivery List.[13] According to the United States Geological Survey (USGS) data for 2017, the global mine production of gold equaled 3150 tons while Swiss Customs data indicates that 2385 tons of unwrought gold was imported into the country (in addition to a relatively negligible 133 kg of gold ore and concentrate).[14] This implies that Swiss refineries and trading firms imported unwrought gold equal to 75% of global annual production in 2017, making it the dominant global hub for gold trade. Finally, Switzerland is also one of the world's largest financial services hub which provides trading firms with vital trade-finance, insurance, logistics, and legal services. This agglomeration of complementary industries is governed by Swiss federal and cantonal regulatory frameworks. Trading companies are subject to an auxiliary status with a tax rate of approximately 11.6% in Geneva, with similarly favorable fiscal rates in other Swiss cantons. Favorable regulatory environment and political and economic stability are also considered important for this industry (Eggert and others, 2017).

Despite the size and significance of the Swiss trading sector for understanding international commodity trade, empirical analysis of this sector is complicated due to certain business characteristics and limitations in data coverage. Firstly, Swiss trading firms' predominant

[10] The authors find that Swiss copper imports from Zambia were approximately 6000 times smaller than reported Zambian exports to Switzerland, which can be linked to the fact that most of the copper was being purchased by Swiss trading firms for re-sales to a third country.

[11] According to the OECD's Global Revenue Statistics Database, tax revenue-to-gross domestic product ratios in year 2015 displayed considerable heterogeneity between and within regions, between 10.8% and 30.3% in Africa and 12.4%–38.6% in Latin America, compared to 16.2%–45.9% in the OECD countries. See: Modica et al. (2018).

[12] Source: STSA Website https://stsa.swiss/.

[13] The list certifies refineries that meet the stringent production quality criteria. For more details, see: http://www.lbma.org.uk/good-delivery-list-about.

[14] Global statistics on gold production available here: https://minerals.usgs.gov/minerals/pubs/commodity/gold/.

activities are transit or merchant trade, whereby the products are bought and sold outside Swiss Customs territory. Information on transit trade is therefore not available in Swiss Federal Customs Administration statistics which only records transactions which physically enter the territory. The Swiss National Bank (SNB) publishes aggregate data on merchanting in the balance of payments (BOP), however this only provides a rough approximation of the magnitude of commodity trading activities since it includes trade in commodities, pharmaceuticals, and chemicals, in addition to net costs of services associated with transit trade including storage, insurance, and processing. Systematically collected firm-level financial and operational statistics on the sector remains publicly unavailable. The Swiss classification of industries (NOGA) does not have any dedicated category for the trading sector, while most companies are privately held and their financial data is considered sensitive due to the highly competitive nature of the sector. As a result of these limitations, we focus our analysis on the available trade micro-data from the Swiss Federal Customs Administration. While this data does not account for merchanting, it can be expected to shed light on pricing patterns of physical trade which enters Swiss Customs territory.

3. Empirical methodology

International trade data is of great economic interest for many reasons. Trade in goods and services have significant effects on a country's economic activity, while contributing a significant share of government revenue through Customs duties. Researchers have also shown that trade data can be used to study corruption, capital flight, and trade misinvoicing, which includes mispricing of transactions. As discussed in the previous section, mispricing of commodity trade transactions is a prominent channel for tax-base erosion from resource-rich developing countries. In order to quantify the magnitude of this phenomenon, researchers have analyzed asymmetries in partner-country trade statistics or examined pricing anomalies in transaction-level data. In this section, we discuss two prominent methods used to estimate trade mispricing: including partner-country trade analysis method introduced by Bhagwati (1964) and Bhagwati and others (1974). This method still represents the dominant approach used by trade economists to estimate proxies for customs fraud and trade mispricing. Next, we present price-filter analysis methods which represent a data-intensive, methodological advancement.

3.1. Partner-country trade gap analysis

Partner-country trade gap analysis is the predominant approach used in the policy and advocacy literature for quantifying the extent of trade misinvoicing (Global Financial Integrity, 2017). Bhagwati (1964) and Bhagwati and others (1974) provided the first analysis based on partner-country trade gaps including a discussion on the incentives involved for trading firms, especially focusing on tax and customs duty evasion. This methodology is based on the principle of double-counting in international trade statistics, whereby the exporting country's statistics are compared to the importing partner's corresponding statistics, i.e. mirror statistics. It is further assumed that advanced countries' trade statistics are reliable and that any unexplained asymmetries in reported trade statistics between advanced and developing trading partners is evidence of trade misinvoicing in developing countries. In other words, the trade statistics of the advanced country represent the arm's length value for the exports and imports of developing countries.

Accordingly, the partner-country trade gap method tests the following *Hypothesis*:

Hypothesis. The export and import values reported by developing countries should equal the corresponding trade values reported by their industrialized trading partners after accounting for transportation and insurance costs.

If the trade statistics reject this *Hypothesis*, the corresponding gaps between the partners' mirror statistics are interpreted as evidence of trade misinvoicing in developing countries. This method is implemented as follows: first, annual import data (measured using cost plus insurance and freight or c.i.f. method) are converted to the free-on-board basis using a standard factor of 10 percent used by the IMF's Direction of Trade Statistics (DOTS). Next, the import and export discrepancies (I.D. and E.D., respectively, as denoted below) are calculated using the following formulae:

$$ID_{j,p,t} = I_{jt} / r - X_{p,t}$$

$$ED_{j,p,t} = I_{p,t} / r - X_{j,t}$$

where:

$\mathbf{I_{j,t}}$ = Imports by country *j* from the partner country *p* at time *t*
$\mathbf{I_{p,t}}$ = Partner country *p*'s imports from the country *j* at time *t*
r = Standard freight and insurance cost adjustment factor of 10 percent
$\mathbf{X_{p,t}}$ = Partner country *p*'s exports to country *j* at time *t*
$\mathbf{X_{j,t}}$ = Country *j*'s exports to partner country *p* at time *t*

These discrepancies or trade gaps are usually calculated at the aggregate level, including all traded product categories, but they can also be calculated at the product level (based on the Harmonized Commodity Description and Coding System or HS code) subject to availability of disaggregated data. Most recent applications of this approach include the empirical literature on IFFs conducted by advocacy organizations and policy institutions.

Methodological Limitations of Partner-Country Trade Gaps: The large estimates of trade-based IFFs generated using this methodology have been critiqued by a number of academic studies (De Wulf, 1981; K. P. Hong and Pak, 2017; Nitsch, 2016; Reuter, 2012). These limitations which can be briefly summarized as follows:

1. **Incorrect to assume that trade statistics in advanced economies exhibit no asymmetries:** The main underlying assumption of is to consider advanced economies' trade statistics as arms-length values for comparison with developing countries' trade statistics. However, Hong and Pak (2017) use both transaction-level trade data from Customs agencies and aggregate trade statistics from the IMF DOTS database to show that significant asymmetries also exist in mirror statistics of trade between advanced economies, thereby making it hard to justify this crucial assumption.
2. **Unobserved trade costs:** Import transactions are valued on a cost, plus insurance and freight (CIF) basis which must be artificially to the free-on-board (FOB) valuation conventionally used for exports before trade gaps can be calculated. Since data on transactions costs of trade are not generally recorded, a 10% rule-of-thumb adjustment has been used for these conversions. This rule of thumb is derived from aggregate differences between global export and import values. Therefore, a standard 10% estimate of trade costs has limited applicability for reliably converting bilateral trade values across all commodities with varying shipping and insurance costs.
3. **Use of aggregate trade statistics:** A majority of this literature focuses on calculating aggregate trade gaps, using total annual exports and imports figures. However, in many cases, bilateral data between trading partners may not be available for all goods and commodities being traded leading to the generation of highly misleading estimates of trade gaps. Furthermore, aggregate trade gaps can mask under or over-invoicing in particular commodities which cancel out in the aggregate.
4. **Exports and import transactions can be recorded in different years:** Depending upon the mode of transport and distance between trading points, international trade can take significant time to complete. This could lead to partners often recording the same

transaction in different years, while the annual trade gaps are calculated using statistics for the same year.

5. **Entrepôt trade:** For several commodities, the source and destination countries recorded in the statistics reflects reporting from intermediate ports where the shipment is warehoused for a time before being shipped to the ultimate destination in other countries. Furthermore, international commodity trading firms can decide to divert shipments in transit to storage warehouses to benefit from arbitrage opportunities when market prices fluctuate. When exports and imports passing through these entrepôt ports are reported by both the entrepôt countries and the exporting-importing partners, this leads to double-counting in official data and generation of artificial trade gaps.
6. **Exchange rates used for currency conversion:** International trade transactions can be conducted either in certain vehicle currencies (e.g., the U.S. dollar) or in local currencies. If different exchange rates are used by trading partners to convert their trade values to USD, this can lead to gaps in their mirror trade statistics. Some developing countries can also maintain multiple exchange rate regimes, thereby amplifying the possibility for such errors.
7. **Country idiosyncrasies:** Any international estimation of trade gaps can also be affected by particular countries who do not report bilateral trade flows for particular goods for particular years for one reason or another. For example: Switzerland is a major destination for gold refining, however it did not report disaggregated, country-level data on its international trade in unwrought gold until 2012.

3.2. Price-filter analysis

Price filter analysis is an alternative methodologies proposed by Zdanowicz et al. (1999) and Hong and others (2014) to analyze abnormal pricing in international trade. This methodology relies on a single country's transaction-level trade microdata on product-type (based on the Harmonized Commodity Description and Coding System or HS code), quantity, and unit value. This data is used to identify the arm's length price range for individual products which is then used to distinguish between normally and abnormally priced transactions. There are two main approaches to applying price filter analysis which are presented below.

Inter-quartile range price filter: This methodology assumes that the inter-quartile range, between the 25th and 75th percentile, of the observed distribution of unit prices for a particular commodity represents the arm's-length price range. Under this approach, the overpriced amount is assumed to be the deviation of the price from the upper-quartile price when a declared unit value (price) is above the upper-quartile price. Similarly, when a declared price is below the lower-quartile price, the underpriced amount is assumed to be the deviation of the price from the lower-quartile price.[15]

Essentially, we test the following *Hypothesis* using the interquartile range price filter method:

Hypothesis. The transaction price for a correctly valued product lies within the arm's length price range defined by the interquartile range of the observed price distribution.

Accordingly, any transaction value which exceeds the 75th percentile or fall below the 25th percentile of the observed price distribution is designated to be abnormally priced. The under or over-valued amounts for each transaction is then calculated as follows:

Undervalued amount = Quantity x MAX(0, LoQ - P)

Overvalued amount = Quantity x MAX(0, P - UpQ)

where:

P = Declared price (unit value implied in quantity and value in each trade record)
LoQ = Lower-quartile price
UpQ = Upper-quartile price

It is relatively straightforward to observe that since the interquartile price range is endogenously estimated using the observed price distribution, this Hypothesis will be rejected by design for a certain proportion of transactions. Therefore, these estimates of trade mispricing should be interpreted carefully and supplemented with further analysis regarding product, price, and individual market characteristics. For example, the level of purity of a precious metal and any contemporaneous political, economic or environmental shocks may play a key role in determining whether the observed transaction price falls within the interquartile price range during a given period. We discuss these limitations in more detail below.

Free-market price filter: This framework compares actual transaction-level unit prices for a particular commodity with their contemporaneous free-market price, plus/minus an assumed range of deviation to account for expected price volatility due to product characteristics, transportation costs, contract terms, and business conditions. This range is assumed to represent the arm's length price range for the particular traded product. All transaction prices within this price range are assumed to be normally priced, while any prices outside the range are designated to be abnormally priced.

More specifically, we test the following Hypothesis by applying this method:

Hypothesis. All normally valued transaction prices for a particular product fall within the arm's length price range defined using the corresponding free-market prices.

The abnormally overvalued amount is estimated as the deviation from the upper bound of the range (P_{High}) and the abnormally undervalued amount as the deviation from the lower bound of the range (P_{Low}). Specifically, the mispriced amount for each transaction is calculated as follows:

Undervalued amount = Quantity x MAX(0, P_{Low} – P)

Overvalued amount = Quantity x MAX(0, P – P_{High})

where:

P = Declared price (unit value implied in the quantity and value in each declared import record)
P_{Low} = Lower bound of the free market price range
P_{High} = Upper bound of the free market price range

The main advantage of using the free-market price filter method is that we do not need to endogenously estimate arm's length price using the observed transaction prices. Therefore, this method is not affected by related party transaction records in the import and export database. However, this method requires easily identifiable and commonly acknowledged benchmark prices which may not be readily available for products where there is no established commodity market.

Methodological Innovations to Address Limitations of Price-Filter Analysis: According to Reuter (2012) and Carbonnier and Zweynert de Cadena (2015), price filter analysis based on trade micro-data is an intuitive methodology, however it has some important limitations in accurately estimating abnormal pricing. Price filter analysis is usually based on product classification at a high level of disaggregation. However, for products which are very heterogeneous in terms of quality and prices, this method can still incorrectly identify high-end

[15] According to Hong and others (2014), this approach is based on the United States' Internal Revenue Service (IRS) transfer pricing regulation, Internal Revenue Code 482, which specifies that an interquartile range is an acceptable arm's length transaction range.

products as overpriced and low-end products as undervalued. Meanwhile, abnormally priced transactions of mid-range products might be wrongly classified as legitimate transactions. Specifically, for interquartile range analysis, the lower- and upper-quartile bounds are estimated based on observed trade transactions. Therefore, as long as there is at least some variation in prices within each commodity, this method will always produce some overpriced and underpriced transactions. Finally, applications of price filter analysis across multiple commodities often do not take into account the potential misinvoicing of quantities instead of prices, i.e. under or over reporting of trade quantities. Since price filter analysis relies on unit prices of transactions, an over or under-reporting of quantities will also bias the estimates of trade mispricing.

In our application of the price filter analysis method, we introduce some methodological innovations to address these limitations. Primarily, we use extensive commodity sector research and expert interviews with traders in Switzerland and abroad on commodity characteristics and supply chains to inform our assumptions regarding the selection of price filters around the free-market prices. The main factors we discuss are product heterogeneity, market conditions and contract terms, and shipping costs. In particular, we identify and combine additional data sources on commodities production and trade to estimate the arm's length price range.

4. Data sources

4.1. Swiss imports data: 2011-17

The main data source for the transaction-level import statistics with daily frequency is the Swiss Federal Customs Administration for the period of analysis 2011–17. Disaggregated data on gold imports by trading partner is only available from 2012 onward, since this information was kept confidential until 2011 due to political economy and business reasons.[16] The selected commodities and their corresponding HS codes, as per Swiss Federal Customs Administration tariff guidelines, are as follows[17]:

- Non-monetary, Unwrought Gold: HS code: 7108.12 (gold doré)
- Refined Copper and Alloys: HS codes: 7403.11 (cathodes), 7403.12 (wire-bars), 7403.13 (billets)
- Cocoa Beans: HS code: 1801.00 (whole or broken, raw or roasted beans)
- Unroasted Coffee Beans: HS code: 901.11 (non-decaffeinated) and 901.12 (decaffeinated)

The summary statistics for the selected commodities are presented in Table 1 below. Aggregate annual data for Swiss imports and rest of the world's exports to Switzerland is also accessed via the United Nations Comtrade database for the corresponding time period.

4.2. Free market commodity price data: 2011-17

We accessed daily-frequency commodity market data from the global financial and macroeconomic database Datastream by Thomson Reuters. The specific commodity exchanges providing this data are listed as follows:

- Gold: London Bullion Market Association (LBMA) - Gold Bullion LBM ($/t oz)
- Copper: London Metals Exchange - LME-Copper, Grade A 3 Months (U$/MT)
- Cocoa Beans: The International Cocoa Organization (ICCO) - Cocoa-ICCO Daily Price (US$/MT)
- Coffee: International Coffee Organization - Coffee-ICO Composite Daily ICA (c/lb)

4.3. Metals Focus gold and silver dore flows service database

We use this proprietary database from the London-based commodity sector consulting firm, Metals Focus, on mine-level information on historical, current and forecasted doré production (up to 2030) by country. It also contains information on current refining location, historic production costs, current mineral reserves and resources, and most relevant for our analysis: gold – silver split in doré production for 652 mines in 77 gold producing countries. According to Metals Focus, the gold content in doré ranges between 2.8% and 95% by weight, while impurities like copper, lead, bismuth and arsenic among others are assumed to comprise up to 5% of doré weight (Metals Focus Gold & Silver Doré Flows Report, 2019).

5. Abnormal pricing estimates

In this section, we present the annual estimates of trade mispricing for the selected commodities based on three different methods, including: free market price filter, interquartile price range filter and partner-country trade gaps. The price filter analysis is based on transaction-level data from Swiss Federal Customs Administration, while the partner-country trade gap analysis uses annual data from the UN Comtrade database.

There are some important distinctions in the interpretation of the estimates from each method which should be considered. Price filter analysis provides the estimated magnitudes of abnormal pricing, i.e. value of product imports which exceeds the assumed arm's length price range. By comparison, the partner-country trade gaps reveal the aggregate asymmetries or gaps between the import value reported by Switzerland and the total export value reported by the rest of the word, i.e. all the trading partners. These gaps have also been interpreted in the literature as evidence of trade mispricing, as discussed in Section 3. However, these estimates are not directly comparable. We calculate estimates from both methods in order to facilitate direct comparison of two different measurement techniques and highlight any statistical issues emerging from the comparison of trade data from different sources and at different levels of aggregation. The price filter analysis results are based on administrative data from a single country, i.e. Switzerland. Therefore, these estimates help us address the limitations associated with comparing mirror statistics.

5.1. Unwrought gold (HS code: 7108.12)

Swiss Federal Customs Administration data indicates that between 2012 and 17, the country imported on average CHF 80.48 billion of non-monetary, unwrought gold annually (corresponding to tariff classification or HS code: 7108.12).[18] Switzerland imports unwrought gold from 133 countries including gold producers (United States, Peru, China, Thailand, Uzbekistan, Russia, etc.), as well as trading and shipping hubs

[16] According to media reports, the arguments used to justify this decision include keeping commercial sensitive information confidential to assisting the Zurich-based commodity exchanges compete against London commodity exchanges, as well as to conceal politically sensitive information about trade relations with apartheid-era South Africa and the Soviet Union. See: https://www.swissinfo.ch/eng/business/international-trade_counting-gold-in-switzerland/41417986 (accessed: September 2018).

[17] Swiss Federal Customs Administration List of Tariff Headings document available here: https://www.ezv.admin.ch/ezv/en/home/information-companies/customs-tariff—tares.html (accessed: February 2018).

[18] We exclude 2854 transactions (approximately 5% of all transactions) below 1 kg by weight to omit small gold ornaments or other non-industrial unwrought gold objects, from our analysis.

(United Kingdom, France, Germany, Belgium, Italy). Unwrought gold imports predominantly comprise of *rough* gold or gold doré bars produced by mining companies or intermediate traders from the extracted gold ore. Doré bars can contain between 2 and 95% pure gold, with the balance made up of silver, copper, other base and platinum group metals, and impurities. Unwrought gold is then traded by middlemen or directly transported by the mining companies to precious metals refineries to be purified up to either 99.5% or 99.99% refined gold bars or other semi-manufactured forms for use as investment assets, jewelry fabrication, or industrial and technological uses.[19]

Free Market Price Filter Methodology: The free-market price used to determine the arm's length price range is the London Bullion Market Association (LBMA)'s daily spot price series for refined gold bars. However according to the Metals Focus Gold Silver Dore Service database, gold doré bars produced and traded internally can contain between 2 and 95% pure gold by weight, silver (ranging between 0 and 92% by weight) and other impurities (up to 5% by weight). Accordingly, we use the country-level gold and silver content in doré produced and calculate a maximum and minimum benchmark price using the following simple formula:

Maximum benchmark price = (daily price of gold * maximum gold content in doré) + (price of silver * minimum silver content)

Minimum benchmark price = (daily price of silver * maximum silver content in doré) + (price of gold * minimum gold content)

Arm's length price range: Next, we use commodity sector research and expert interviews to determine the magnitude of normal price deviations around these benchmark prices. Accordingly, we take into account the following criteria:

- **Transport and insurance costs (+):** Imported product values are usually recorded on Cost plus Insurance and Freight (CIF) basis. The standard assumption in the trade economics literature is to assume that these costs equal 10% of recorded import values. However, since gold is highly valuable precious metal, the transportation and insurance costs constitute a lower proportion of the final value. According to Cadot et al. (2013), the transportation and insurance costs for a trans-continental shipment of gold between major markets can reach up to 2% of the shipment value. This is validated as an upper bound for transportation costs by gold sector experts, who also indicate that location swaps are preferred (Swiss Trading and Shipping Association, personal communication, July 2019). [20]
- **Production costs and Contract terms (±):** Observed variation in transaction prices around the global benchmark also occurs due to differences in mine-level and country-level production costs and fiscal agreements on mining, as well as variation in contract-types between transacting parties. For example, gold ore extraction, processing, storage, and insurance costs can vary significantly by source country. Furthermore, large-scale mining companies often have advance pricing agreements with local governments as well as higher investment and operating costs, compared to small-medium scale and artisanal miners. As a result, we assume variation up to 5% in observed transaction values in either direction compared to the benchmark market value (Metals Focus Gold Silver Dore Database, 2019).

Based on these factors, we conservatively assume an arm's length price range of plus and minus 5% around the country-level benchmarks calculated above.

Results: The estimates for undervalued imports are reported in Table 2 and the corresponding estimates for overvalued imports are in Table 3. Based on the above estimations, the results from free-market price filter analysis indicate that a significant magnitude of Swiss gold imports are abnormally under-valued. During 2012–17, the estimated magnitude of undervalued imports equals CHF 21.7 billion, which equals approximately 4.5% of the total value of imports during this period. By comparison, the magnitude of overvalued imports is negligible (CHF 18.4 million). We discuss various factors which could be driving this large magnitude of under-valued gold imports in Section 5.1. Most prominently, we discuss the implications of significant product heterogeneity in terms of differences in gold production costs and purity based on source, as well as concerns regarding the bargaining power of artisanal and small-scale gold mining companies and traders in negotiating transaction prices using the benchmark, free-market prices. Furthermore, we also discuss the potential impacts of gold derivatives trading in the spot and futures markets in London and New York in driving the benchmark prices, rather than the physical demand and supply of gold.

Partner-Country Trade Gaps: Next, we also consider the asymmetries or trade gaps between unwrought gold imports recorded by Switzerland and exports to Switzerland recorded by the rest of the world. By design, this method can only generate either positive, i.e. reported Swiss annual import value exceeds reported exports to Switzerland by trading partners (interpreted as capital inflows to Switzerland via underpriced exports from trading partners) or negative estimates, i.e. reported Swiss annual import value is lower than exports to Switzerland reported by trading partners (interpreted as capital outflows from Switzerland via overvalued exports from trading partners). The results indicate significant, positive trade gaps equaling CHF 218.03 billion in the period 2012–17. On face value, these gaps are indicative of under-invoicing by exporters and illicit inflows of financial capital into Switzerland.

Table 2
Undervalued imports – unwrought gold.

Year	Import Value (CHF, million)	Free Market Price Filter (CHF, million)	Partner-country Method: (CHF, million)
2012	88,971	3438	-
2013	109,612	8733	-
2014	65,151	5542	-
2015	68,220	1973	-
2016	81,805	874	-
2017	69,096	1164	-
Mean	**80,476**	**3621**	-
Total	**482,857**	**21,726**	-

Data Source: Swiss Customs Administration; United Nations COMTRADE.
Notes: Product category includes unwrought gold (HS: 7108.12) imports for period 2012–17. Switzerland does not report gold trade data till 2011. Since this customs classification may also record unwrought gold ornaments and other gold products transported in smaller quantities, we exclude transactions below 1 kg by weight (N = 2854). The objective is to focus on larger transactions of gold doré. **Free market price** is the daily Gold Bullion price from London Bullion Market (US$ per troy ounce, converted to CHF per kilogram using daily US$-CHF exchange rate). **Partner-country trade gaps** equal the difference between annual imports from rest of the world by Switzerland and reported exports by rest of the world to Switzerland (US$ converted to CHF using annual average exchange rate from UNCTADStat). This difference can be either positive or negative, implying either over-valued or under-valued imports in any given year.

[19] See the report by the Platform for Collaboration on Tax (2017) for a detailed discussion on the gold supply chain and valuation.

[20] Loco swaps are a way to move gold or silver to another location without physically shipping it. It is a transaction where two parties agree to exchange (swap) gold they have in different locations (locos) with each other. Since gold trades at marginally different prices in different locations. This means that the loco discount or premium needs to be transferred between the swap parties in addition to the metal itself.

Table 3
Overvalued imports – unwrought gold.

Year	Import Value (CHF, million)	Free Market Price Filter (CHF, million)	Partner-country Method: Swiss Imports – 1.1*RoW Exports (CHF, million)
2012	88,971	0.98	22,206
2013	109,612	5.37	65,964
2014	65,151	0.08	25,222
2015	68,220	9.51	32,212
2016	81,805	2.26	34,550
2017	69,096	0.18	37,879
Mean	**80,476**	**3.07**	**36,339**
Total	**482,857**	**18.39**	**218,033**

Data Source: Swiss Customs Administration; United Nations COMTRADE.
Notes: Product category includes unwrought gold (HS: 7108.12) imports for period 2012–17. Switzerland does not report gold trade data till 2011. Since this customs classification may also record unwrought gold ornaments and other gold products usually shipped in small quantities, we exclude transactions below 1 kg by weight (N = 2854). The objective is to focus on larger transactions of gold doré. **Free market price** is the daily Gold Bullion price from London Bullion Market (US$ per troy ounce, converted to CHF per kilogram using daily US$-CHF exchange rate). **Partner-country trade gaps** equal the difference between annual imports from rest of the world by Switzerland and reported exports by rest of the world to Switzerland (US$ converted to CHF using annual average exchange rate from UNCTADStat). This difference can be either positive or negative, implying either over-valued or under-valued imports in any given year.

5.2. Refined copper cathodes (HS code: 7403.11)

Next, we consider Swiss imports of refined copper cathodes for period 2011–17. These imports consist of 99.9% pure copper cathodes manufactured by mining companies after extracting and processing copper ore and concentrate. These cathodes are sold primarily to fabricators of semi-manufactured products demanded by final consumers. Copper cathodes are produced and traded under several grades, with lower grades used for low conductivity appliances and alloys. London Metal Exchange (LME)-accredited copper refineries can manufacture LME registered High (A) Grade cathodes, while Non-LME registered High (A) grade cathodes, Standard Grade cathodes and off-grade cathodes are also produced and traded.

Overall, data from the Swiss Federal Customs Administration indicates that recorded physical imports of refined copper into Switzerland are very minor (equal to CHF 4.2 million per year on average between 2011 and 17) and the low number of transactions (359 transactions from rest of the world across 7 years) preclude our ability to conduct reliable price filter analysis. As a result, we focus our analysis of refined copper using mirror statistics.

Partner-Country Trade Gaps: Our analysis of aggregate trade statistics from UN Comtrade immediately show an unusual pattern: while recorded Swiss imports are very minor (equal to CHF 4.2 million per year on average between 2011 and 17), the recorded exports of refined copper by the rest of the world to Switzerland is more than 500 times larger (equal to CHF 2.3 billion per year on average between 2011 and 17, see Table 4). As a result, the observed trade gaps in aggregate data are systematically negative. We hypothesize that this is an example of a "*Switzerland effect*" in international commodity trading statistics, which is driven by merchanting or transit trade operations of Swiss trading firms. In effect, the copper is being reported as sold to Switzerland by the exporter however, the product is physically stored and re-sold to a buyer in a third country. As a result, we expect this effect to distort the international trade statistics of refined copper cathodes.

5.3. Cocoa beans (HS code: 1801.00)

Next we analyze cocoa beans, which is an important agricultural commodity for Swiss trading and consumer food production companies. The traded cocoa beans are produced after fermentation and drying of the raw beans and are used in the manufacturing of processed foods, including chocolate and cocoa powder. The two dominant sources of cocoa beans traded internationally include Ivory Coast and Ghana, however Switzerland also imports significant amounts of cocoa from Ecuador, Madagascar, and Peru. In addition, Switzerland also imports cocoa beans from Italy, Belgium, Germany, and Netherlands but these are trading and shipping hubs for the product. Finally, we confirm that Switzerland is a major consumer of cocoa beans by checking that imports far exceed exports of cocoa beans, which are very minor in value (CHF 1.5 million exported by Switzerland in 2016, compared to CHF 128 million in imports).

Interquartile Price Filter Methodology: As discussed in Section 1, we prefer the estimates based on interquartile price range calculated at the exporter-year level for cocoa beans. The Swiss imports data does not allow us to differentiate between different types of cocoa beans in each transaction imported into Switzerland, in order to determine their corresponding benchmark prices.

Findings: The estimates for under and over-valued imports are

Table 4
Undervalued imports: Refined copper.

Year	Imports Value (CHF, million)	Partner-country Method: Swiss Imports – 1.1*RoW Exports (CHF, million)
2011	4.62	- 3725
2012	4.89	- 3583
2013	6.39	- 3669
2014	5.76	- 3876
2015	2.30	- 2590
2016	2.55	- 299
2017	3.34	- 256
Mean	**4.26**	**- 2571**
Total	**29.84**	**- 18,003**

Data Source: Swiss Customs Administration; United Nations COMTRADE.
Notes: Product categories include refined copper cathodes and sections of cathodes (HS: 7403.11) for period 2011–17. **Partner-country trade gaps** equal the difference between annual imports from rest of the world by Switzerland and reported exports by rest of the world to Switzerland (US$ converted to CHF using annual average exchange rate from UNCTADStat).

Table 5
Undervalued imports - cocoa beans.

Year	Import Value (CHF, million)	Interquartile Range Filter: Below 25th pctle. (CHF, million)	Partner-country Method: Swiss Imports - 1.1*RoW Exports (CHF, million)
2011	143.79	2.66	-
2012	133.49	4.82	-
2013	118.67	2.01	-
2014	130.69	1.70	-
2015	143.13	7.07	-
2016	125.06	18.37	-
2017	129.76	8.07	-
Mean	**132.08**	**6.39**	-
Total	**924.59**	**44.71**	-

Data Source: Swiss Customs Administration; United Nations COMTRADE.
Notes: Product category includes cocoa beans (HS: 1801.00) for period 2011–17. **Interquartile range** is calculated at the exporter-year level for unit prices (CHF per kg) using transaction-level Swiss Customs data. **Partner-country trade gaps** equal the difference between annual imports from rest of the world by Switzerland and reported exports by rest of the world to Switzerland (US$ converted to CHF using annual average exchange rate from UNCTADStat). This difference can be either positive or negative, implying either over-valued or under-valued imports in any given year.

Table 6
Overvalued imports - cocoa beans.

Year	Import Value (CHF, million)	Interquartile Range Filter: Above 75th pctle. (CHF, million)	Partner-country Method: Swiss Imports - 1.1*RoW Exports (CHF, million)
2011	143.79	2.13	115.71
2012	133.49	1.95	93.74
2013	118.67	1.80	95.85
2014	130.69	2.02	105.50
2015	143.13	2.77	121.45
2016	125.06	2.48	108.60
2017	129.76	2.39	125.53
Mean	**132.08**	**2.22**	**109.48**
Total	**924.59**	**15.55**	**766.38**

Data Source: Swiss Customs Administration; United Nations COMTRADE.
Notes: Product category includes cocoa beans (HS: 1801.00) for period 2011–17. **Interquartile range** is calculated at the exporter-year level for unit prices (CHF per kg) using transaction-level Swiss Customs data. **Partner-country trade gaps** equal the difference between annual imports from rest of the world by Switzerland and reported exports by rest of the world to Switzerland (US$ converted to CHF using annual average exchange rate from UNCTADStat). This difference can be either positive or negative, implying either over-valued or under-valued imports in any given year.

reported in Tables 5 and 6 respectively. Our findings are as follows: abnormally under-valued imports equal CHF 44.71 million or 4.8% of total imports, while abnormally over-valued imports equal CHF 15.55 million or 1.7% of total imports between 2011 and 17. Overall, these estimates indicate that abnormal pricing defined by excessive variance in transaction prices may not be a significant concern for cocoa bean imports since only a small share (by value) of transactions are valued outside the interquartile range of observed prices. The main trading partners where abnormally undervalued imports are recorded from include, Ghana (CHF 6.18 million), Ecuador (CHF 4.29 million), Germany (CHF 3.72 million) and Dominican Republic (CHF 2.66 million).

More detailed information regarding the nature of underlying transactions and their financial terms can provide regulators more visibility regarding the key drivers of these estimations. It is especially important to consider the impact of financial derivatives that are used to provide advance liquidity and hedge risk by producers and traders of cocoa. For example: Ghana's Cocoa Marketing Board sells a dominant share of their cocoa beans production up to a year in advance using future contacts, which are actively traded on commodity exchanges. Significant trading in cocoa derivatives also takes place in commodities exchanges but which is not linked to the demand and supply of physical commodity which can be stored in off-share storage houses for up to 5 years.

Partner Country Trade Gap Methodology: Finally, we observe that the partner country trade gaps are systematically positive and significantly larger than the abnormal pricing estimates based on transaction-level data. This implies that Switzerland is reporting higher import values than those reported by its trading partners. Unlike the case of gold trade, we have already verified that Switzerland is not a processing hub for cocoa beans but is more likely the final consumer given the negligible cocoa exports from Switzerland. As a result, we hypothesize that these large positive asymmetries could be driven due to an entrepôt trade effect whereby exporting countries are recording intermediate shipping or storage hubs as the final destination of their exports. However, these products are finally shipped to Switzerland, which records the original source country as the exporter. The value of final imports into Switzerland may also be distorted since trading firms take advantage of price arbitrage opportunities by storing the cocoa beans in intermediate hubs.

5.4. Unroasted coffee beans (Non-decaffeinated HS code: 0901.11 and decaffeinated HS code: 0901.12)

Finally, we analyze coffee beans as another agricultural product traded and consumed by Swiss trading and consumer food firms. There are two main types of coffee beans: Robusta and Arabica, but coffee is a significantly heterogeneous commodity that is differentiated by bean type and natural conditions such as altitude, latitude, and volcanic soil. After harvesting, coffee beans are transported to processing mills for processing, sorting, and grading by size, weight, and form. Processing coffee involves converting the raw fruit of the coffee cherry into the green (dried) coffee beans. International coffee trade mostly involves green coffee (dried berries) packed in 130-pound bags. Coffee roasting is usually completed by the final processing company or at a coffee house after blending coffee beans of different origin and type together.

Interquartile Price Filter Methodology: For our analysis, we will use data on unroasted coffee beans, both non-decaffeinated and decaffeinated (HS: 901.11 and 901.12, respectively) for period 2011–17. Similar as cocoa, we prefer the abnormal pricing estimates based on interquartile range price filters. The Swiss imports data does not allow us to differentiate between different types of beans in each transaction imported into Switzerland, in order to determine their corresponding benchmark prices.

Findings: The estimates for undervalued imports are reported in Table 7 and the corresponding estimates for overvalued imports are in Table 8. Same as for cocoa, our results show relatively minor magnitudes of abnormally under-valued imports, equal to CHF 128.9 million (3% of total imports) and CHF 104.12 (2.4% of total imports) of abnormally over-valued imports between 2011 and 17. these estimates indicate that abnormal pricing defined by excessive variance in transaction prices may not be a significant concern for cocoa bean imports since only a small share (by value) of transactions are valued outside the interquartile range of observed prices. The main trading partners where abnormally undervalued imports are recorded from include, Brazil (CHF 36.62 million), Colombia (CHF 20.70 million), Ethiopia (CHF 10.51 million), Guatemala (CHF 8.92 million) and India (CHF 7.79 million).

Partner Country Trade Gaps: Finally, we once again observe that the partner country trade gaps are systematically positive and significantly larger than the abnormal pricing estimates based on transaction-level data. We verify that Switzerland is not a transit hub but is more

Table 7
Undervalued imports - coffee beans, not roasted.

Year	Import Value (CHF, million)	Interquartile Range Filter: Below 25th pctle. (CHF, million)	Partner-country Method: Swiss Imports - 1.1*RoW Exports (CHF, million)
2011	695.87	25.81	-
2012	660.38	15.08	-
2013	567.24	15.05	-
2014	567.51	13.87	-
2015	652.25	21.12	-
2016	582.98	17.01	-
2017	629.24	20.90	-
Mean	**622.21**	**18.41**	-
Total	**4355.47**	**128.85**	-

Data Source: Swiss Customs Administration; United Nations COMTRADE.
Notes: Product categories include coffee beans, not roasted, decaffeinated and not-decaffeinated (HS: 901.11 and 901.12) for period 2011–17. **Interquartile range** is calculated at the exporter-year level for unit prices (CHF per kg) using transaction-level Swiss Customs data. **Partner-country trade gaps** equal the difference between annual imports from rest of the world by Switzerland and reported exports by rest of the world to Switzerland (US$ converted to CHF using annual average exchange rate from UNCTADStat). This difference can be either positive or negative, implying either over-valued or under-valued imports in any given year.

Table 8
Overvalued imports - coffee beans, not roasted.

Year	Import Value (CHF, million)	Interquartile Range Filter: Above 75th pctle. (CHF, million)	Partner-country Method: Swiss Imports - 1.1*RoW Exports (CHF, million)
2011	695.87	14.93	256.70
2012	660.38	17.69	326.66
2013	567.24	11.58	283.00
2014	567.51	15.36	335.36
2015	652.25	14.32	412.71
2016	582.98	17.78	351.49
2017	629.24	12.46	505.17
Mean	**622.21**	**14.87**	**353.01**
Total	**4355.47**	**104.12**	**2471.09**

Data Source: Swiss Customs Administration; United Nations COMTRADE.
Notes: Product categories include coffee beans, not roasted, decaffeinated and not-decaffeinated (HS: 901.11 and 901.12) for period 2011–17. **Interquartile range** is calculated at the exporter-year level for unit prices (CHF per kg) using transaction-level Swiss Customs data. **Partner-country trade gaps** equal the difference between annual imports from rest of the world by Switzerland and reported exports by rest of the world to Switzerland (US$ converted to CHF using annual average exchange rate from UNCTADStat). This difference can be either positive or negative, implying either over-valued or under-valued imports in any given year.

likely the final consumer given the negligible exports of unroasted coffee beans. As a result, we hypothesize that these large positive asymmetries could be driven due to an *entrepôt trade* effect whereby exporting countries are recording intermediate shipping or storage hubs as the final destination of their exports. However, these products are finally shipped to Switzerland, which records the original source country as the exporter. The value of Swiss import transactions could also be distorted by trading firms storing the beans in intermediate hubs to take advantage of price arbitrage opportunities. Finally, as with the other commodities, trade mispricing and customs fraud are other potential factors driving these asymmetries, but it is not possible to reliably estimate their magnitude using aggregate trade data.

6. Conclusions and policy implications

Illicit financial flows (IFFs) through commodity trade mispricing are argued to pose a significant development challenge for resource-rich, developing countries by eroding their tax base. Two overlapping channels have been identified by researchers, including trade misinvoicing and abusive transfer pricing. This paper contributes new evidence to the IFF literature by estimating the magnitude of abnormal pricing, i.e. magnitude of trade valued outside arm's length range, for Swiss commodity imports from the rest of the world. This analysis is based on price-filter analysis whereby transaction-level prices are compared to free market prices from commodity exchanges or trading bodies, as well as with endogenously calculated interquartile price range. We compare these abnormal pricing estimates with the more commonly used asymmetries observed in aggregate, product-level data. Switzerland provides an interesting case study for analyzing abnormal pricing in commodity trade given its status as a trading hub, however it also poses some challenges given the heterogeneity in potential partner-country characteristics driving abnormal pricing.

Some policy recommendations to address the IFF risks identified are as follows. ***First***, our research shows that two most significant risks for trade-based IFFs, i.e. trade mispricing and transfer mispricing, remain hidden due to a lack of adequate statistical infrastructure, even in the case of an advanced trading hub like Switzerland. High-value precious metals, like gold, are more prone to be a conduit for trade-based IFFs. However, the product classification system used by national trade and customs administrations for precious metals remains highly aggregated and lacks transparency regarding important valuation criteria like purity and presence of other precious metals in alloy form. Combined with lack of regulatory oversight in the form of customs valuation audits, this contributes to maintaining an infrastructure conducive to IFFs. Moreover, customs administrations often do not record whether physical trade occurs between related business entities, i.e. transfer pricing transactions. Related entities often include affiliates of multinational firms with an obvious economic incentive to reduce their global tax liabilities by indulging in aggressive transfer pricing in order to shift their taxable income to low tax jurisdictions. This behavior is often aided by the fact that many low-income countries have suffer from regulatory loopholes to regulate transfer pricing within their legal jurisdictions (for example: Ghana). As a result, we recommend an urgent need for resource-rich developing countries and trading hubs to recognize the need for improved transparency in global trade governance by upgrading their trade statistics infrastructure to shed light on these IFF risks. The global system for tariff classification of traded products is managed by the World Customs Organization and offers standardized categorization up to 6-digit codes. However, each country or regional trading union has the ability to further sub-categorize distinct products up to the 10-digit level which offers an opportunity to enhance transparency using specific product definitions.

Second, trading hubs in advanced nations like Switzerland should evaluate unintended consequences of tax incentives offered by trading hubs to attract trading industry. These tax incentives usually take the form of exemptions on importing and trading valuable products. For instance, Switzerland's Value Added Tax rules exempt gold products, including coin, bars, and especially unprocessed, semi-manufactured and scrap gold, from taxation. Furthermore, any alloy containing two or more percent by weight of gold constitutes the legal definition of gold.[21] Similarly, Singapore exempts investment grade precious metals from its Goods and Services Tax regime with the aim of raising Singapore's share in the global precious metals market.[22] Moreover, special zero-tax measures are given to gold trading and local exchange markets of precious metals such as the Singapore Precious Metals Exchange (Financial Action Task Force, 2016b). Finally, Dubai's Multi Commodities Centre free trade zone offers zero personal and corporate tax rates for registered firms, while also offering renewable tax exemptions ('tax holidays') for 15–50 years.[23]

Third, resource-rich developing countries should rigorously evaluate the fiscal incentives offered to attract foreign investment natural resource sector to magnifying IFF-risks in resource-rich, developing countries. These incentives include holidays on corporate tax and royalties, reduced import taxes for capital intensive imports, and Value Added Tax exemptions which are used policy tools to attract foreign investment. However, poorly designed and implemented fiscal measures can extract a significant cost from the domestic tax base in exchange for uncertain benefits. Most significantly, they also create incentives for trade misinvoicing and IFFs from resource-rich countries especially when combined with lack of transparency and inadequate data recording practices, especially within Customs statistics (IISD, 2019). While each sovereign state has the right to establish its own fiscal policies, the global economic governance landscape has shifted since the financial crisis due to the multilateral efforts to adapt financial and taxation rules to curb tax base erosion and aggressive profit shifting, money laundering and criminal financing. Concurrently, however, the proliferation of tax incentives combined with regulatory limitations and lack of transparency, especially within the economically crucial

[21] As per Article 44, Ordinance on Value Added Tax by the Swiss Federal Council, 2009. For more details, see: https://www.admin.ch/opc/en/classified-compilation/20091866/index.html.
[22] For more details, see: https://www.iras.gov.sg/irashome/uploadedFiles/IRASHome/e-Tax_Guides/etaxguide_GST%20Exemption%20of%20Investment%20Precious%20Metals_(Twelfth%20Edition).pdf.
[23] For more details, see: https://www.dmcc.ae/about-us.

commodities sector, contributes to the persistence of significant risks for IFFs. The IFF risks asymmetrically threaten developing economies who have more to lose due to low existing tax base and institutional challenges to mobilize additional public revenues to finance basic public services.

Finally, a number of innovative technologies hold the potential to transform international trade in the coming years. If their potential is harnessed through focused research and development by resource-rich countries and trading hubs, these technologies offer a vital opportunity to improve existing trade governance systems by making the trade value chains more transparent, efficient and robust to IFF-related practices. Similar to past technologies like Radio Frequency Identification (RFID) to identify and trace shipments, blockchain and blockchain-based distributed ledger technologies can have tremendous impact on the global trade supply chain by improving transparency for critical high value products. Similarly, artificial intelligence and machine learning-based platforms combined with FinTech services are being explored to optimize trade shipping routes and reduce transaction and logistics costs Lund and Bughin, 2019; Fan and Chiffelle, 2018). In other financial sectors, these technologies have also demonstrated significant reliability in detecting fraud and abnormal patterns in statistics. Combined with our research insights on IFF channels and risks, these technologies offer a significant advance to any existing platforms to identify and respond to IFFs via trade and transfer mispricing.

Author statement

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