1.1. Price Filter Method (PFM) +

Concept and assumptions
The PFM is a bottom-up method which estimates a price filter for each commodity and uses it as a proxy for arm's length prices. Trade mispricing occurs when the unit price of a given transaction differs from the normal prices assumed by a price filter, i.e., when an abnormal price of a particular transaction is identified. Price filters vary between transactions depending on the circumstances of a given transaction, such as economic circumstances, business strategies of the buyer/seller, contractual terms etc. Price filter's upper and lower bound prices may be obtained from observable market prices or statistical estimates for each commodity (e.g., quartiles).

The main advantage of PFM is that it uses transaction level data. This means that it operates efficiently and at low costs. First, for administrative purposes it can help with automated monitoring of transactions in real time, allowing for inspection of historical records. Moreover, PFM does not rely on the partner’s transaction data – it can detect mispricing also in the case of collusion of both, importer and exporter, which would not be detected by PCM.

The major drawback of PFM is the fact that statistical price filters will always find transactions with abnormal prices. Statistical price filters, namely, are generated endogenously, i.e., using all available transactions, including abnormally priced transactions. They are constructed by using, for example, the inter-quartile range. PFM will, therefore, always find transactions falling outside the statistical filter.

The next limitation comes with the heterogeneity of products even at transaction level. The transactions need to be classified using product classifications, and even at the most detailed level, they include products of varying degree of heterogeneity. These would inherently have different prices that would be picked up as abnormal prices using the price filter, while that would not necessarily be a sign of mispricing (e.g., high-end quality products within the same product code would have high(er) prices, potentially identified as abnormal prices, whereas in reality they simply reflect the quality of the product).

Moreover, PFM suffers from the inability to identify legitimate unusual prices, e.g., lower prices offered by long-term contracts, but also cases of volatile prices during the price filter estimation period, e.g., using annual price filters for crude oil when monthly crude oil price ranged between US$56/barrel and US$110/barrel in 2014 (see WCO, 2018). Similarly, when declared prices are different from true prices only by a small margin, PFM will not detect them as abnormal prices. Lastly, as in other methods, there is a difficulty to identify recording errors.

Overcoming limitations
These issues can, however, be mitigated by a detailed examination of trade records and/or refinement of price filters for selected commodities, or partners (e.g., accounting for transfer pricing). Although this requires significant efforts by compilers, such commodity or partners country enhancement of the PFM (hence, PFM+) produces better accuracy of estimating IFFs:

1 PFM is subject to an important limitation: it does not capture mis-recording of quantities (which may not be insignificant, specifically in cases of only small-scale mispricing).
1. **Set price filter at a detailed level.** Price filters identified at the most detailed HS-code level depict segmented market features better and lead to a better identification of abnormal prices. Even at the lowest level of product classification, products can exhibit varying quality levels. Supplementing a low-level product code with a description of the commodity may address the problem of false identification of abnormal prices, where in fact, different products are being sold (e.g., high, medium, and low-quality products). Gold\(^2\), technical or IT products seem like natural candidates for such quality variations within a single product code. As in adjustment number 3 below, experts’ knowledge is essential here too. A statistical tool of hedonic prices (see ILO et al., 2004) can also be applied, though the approach has not been tested yet. Moreover, price filters can be refined for each trading partner. Since the input data are at the transactions level, it is possible to look at companies as trading partners (as compared to countries in PCM). It may be useful to detect separately trade mispricing, an activity within IFFs from illegal commercial activities, and transfer mispricing, an activity within IFFs from aggressive tax avoidance. This helps identify potentially different level of abnormality among partners that are members of the same MNE\(^3\). This, however, requires additional data to identify units belonging to the same MNE, e.g., from the statistics business register, the global groups register (in the future) or based on other inputs from the LCU. Transfer mispricing, however, is more prevalent with respect to services and intangibles in general.

2. **Use free-market prices for the filter.** To avoid the issue of endogeneity in setting up the price filter, compilers can rely on free-market prices for traded commodities. These may set a more objective price filter. However, this would require benchmark prices that are easily available and commonly acceptable. These may not be readily available for all products, e.g., without an established commodity market. To counteract this, moving averages of observed transaction prices can also be used in statistical filters.

3. **Consult experts of international trade and examine trade documents.** Applying expert knowledge in determining the price filter is crucial for reliability. The price filter is set as a central price (average, moving-average, free-market price) +/- some level of variation. Experts’ inputs are essential for selecting the central price, but also to set the upper and lower bounds of the price filter. Commodity specialists from national agencies, such as Customs, or related institutions are best placed to support this exercise. Within NSOs, LCUs may have expertise related to strategic pricing by MNEs. Application of mixed research methods, both qualitative and quantitative approaches, allows for a richer insight. Moreover, expert knowledge is also required in additional checks and examination of trade documents in cases of suspicious transactions. These, identified by PFM, need to be examined to avoid false positives. Collaboration of national authorities (NSOs, Customs and others) can help build the knowledge for identifying abnormal prices and addressing IFFs from trade mis invoicing.

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**Source data**

Transaction level data on international trade flows from Customs or other relevant national authorities are used as a source. These contain data on trading partners (companies), flows, price, value, quantity, products at the most detailed level of HS classification, and whenever possible, additionally to the

---

\(^2\) For a case of gold purity, see Carbonnier and Mehrotra (2020).

\(^3\) Carbonnier and Mehrotra (2020) point out that if international trade in a particular commodity is dominated by related parties with an incentive to deviate from arm’s length prices, the estimated interquartile range [price filter] may be biased.
detailed code, also a description of the commodity. It is useful for the NSO and Customs to work together to prepare, clean and classify these datasets. Moreover, it is important to use microdata before certain adjustments are made. For instance, statistical authorities may correct for abnormal prices to produce better quality statistics from the trade transactions data. The IMTS manual (UNSD, 2013) recommends adjustment of invoice values of related partner transactions so that the price matches the market price.

Free-market prices of commodities can be sourced from international data sources, such as UNCTAD commodity prices or the World Bank’s commodity market prices. Similarly, United Nations Comtrade offers a range of standard unit values (SUV) with global unit values including their acceptable range unit value for each HS sub-heading. These sources may be overly aggregated, however alongside experts’ inputs they provide good basis for at least some of the commodities being heavily traded worldwide. Additional insight from (national) experts are required to determine specific commodity price filters.

In cases of bringing trading partners (companies) into analysis (e.g., transfer pricing), structural business statistics at micro-level need to be linked to transactions data, combining them also, when appropriate or available, with automatic exchange of economic data with respect to MNEs (such as OECD’s CbCR data or ADIMA database).

Calculation
Once source data are gathered and prepared, PFM is implemented in the following phases:

1. Exploratory data analysis and preparation of the data

For the analysis, as the first step, the unit of observation is normally defined as a daily aggregation of transactions for a specific commodity (at most detailed available level, e.g., at 8-digit HS) per trading partners (at company levels). This first step involves also obtaining data for imports and exports.

Second step involves aggregating or grouping transactions into groups of similar trades, by commodity, trading partners, time period (depending on volatility, seasonality of prices, this can be from days, to weeks, months, or even a year; we propose daily aggregations), units of measurement (if applicable).

Third step builds on the previous and checks data for outliers, inspect them thoroughly also with experts, and defines the way they are treated (one obvious treatment would be their removal). Case study 1 presents an example of basic treatment of source data held by the South African Revenue Service (SARS) before the application of PFM.

Case study 1. The basic treatment of SARS data prior to applying the PFM

WCO (2018) applied PFM to South Africa’s imports using transaction data by SARS. Basic treatment of these data before the application of PFM itself involved three passes through the data, with each applying standard statistical criteria to screen out extreme values. The PFM was, namely, applied to the SARS sample that required first elimination of outliers that could be the result of errors and would potentially exert undue influence on the results, if included. WCO (2018)

4 Like PCM, also before implementing PFM an exploratory analysis can be conducted, narrowing down the scope, e.g., to only the top-10 traded products, or covering at least 75 per cent of the total trade. This choice will depend on the national circumstances and availability of resources.
notes that with a large sample, such as the SARS database, the potential for such overly influential observations is not negligible. It is also important to note that the PFM was implemented by organizing SARS price data into groups of similar trades, defined by the year of the transaction, commodity traded (8-digit SARS commodity classification) and the unit of measurement.

1. On the first pass to identify admissible groups of transactions, size of the group was checked. Groups with fewer than five observations were eliminated outright and those groups with five or more observations but limited variability in the prices were also eliminated from further analysis.

2. The second pass to identify admissible price observations within groups checked individual prices within the groups passing through first pass, removing the within-group outliers.

3. Third pass aimed at identifying admissible price observations across groups, whereby first standardizing remaining prices to allow comparison across groups. Outliers were removed.

The triple-pass treatment reduced the number of distinct groups from 40,737 to 36,487, and the number of admissible records in the SARS database to just over 7 million. The PFM procedure was then applied to each surviving record in the SARS sample.

2. Including experts of international trade

Second phase is the inclusion of trade experts in the process of applying PFM. We list this as a second phase, although it can be done in first phase already and is to be continued throughout the process of PFM application. Extensive desktop research is crucial to identify relevant national stakeholders (see Part III, Chapter 2). Depending on national circumstances, agencies or institutions these experts come from vary, but could include Customs, frontier or border agencies, private and public agencies specialising in imports and exports procedures, Tax authorities, think tanks and economic-research institutes. Different commodities may require different institutions and/or experts to be involved. Case study 2 showcases this phase in the study of mispricing of gold and cocoa exports from Ghana (Ahene-Codjoe et al., 2020).

Case study 2. Identifying national experts to support the application of the Price Filter Method

In their study of mispricing related to gold and cocoa exports from Ghana, Ahene-Codjoe et al. (2020) conducted extensive research to identify national experts for interviews during other statistical analyses.

List of institutions contacted in Ghana

<table>
<thead>
<tr>
<th>Role of Institution</th>
<th>Name of Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cocoa Beans and Cocoa Paste</td>
<td></td>
</tr>
<tr>
<td>Production</td>
<td>Ghana Cocoa Board (COCOBOD)</td>
</tr>
<tr>
<td>Transportation</td>
<td></td>
</tr>
<tr>
<td>Export</td>
<td>Cocoa Marketing Company (CMC)</td>
</tr>
<tr>
<td></td>
<td>(COCOBOD), Ghana Export Promotion Authority (GEPA)</td>
</tr>
<tr>
<td>Gold</td>
<td></td>
</tr>
<tr>
<td>Regulator</td>
<td>Minerals Commission</td>
</tr>
<tr>
<td>Private Sector Organisation</td>
<td>Ghana Chamber of Mines, Freight Forwarding Agency, Gold Exporting Agencies 1, 2</td>
</tr>
<tr>
<td>Assaying/Valuation</td>
<td>Precious Minerals Marketing Company (PMMC)</td>
</tr>
<tr>
<td>Civil Society Organisations</td>
<td>Ghana Extractive Industries Transparency Initiative (GHEITI), Integrated Social Development Centre (ISODEC)</td>
</tr>
<tr>
<td>Natural Resource Sector Governance</td>
<td></td>
</tr>
<tr>
<td>Purpose of Institution</td>
<td>Name of Institution</td>
</tr>
</tbody>
</table>
3. Defining the price filter

Third phase defines the price filter. Several options are possible, including various enhancements as described above. Regardless, setting-up the price filter is composed of two steps: first, to define the central price, \( c_p \), and second to define the range, \( \alpha \):

\[
price\_filter_{f,c,r,p,t,u} = c_p_{f,c,r,p,t,u} \pm \alpha_{f,c,r,p,t,u} \quad Equation \ (14)
\]

First, decisions need to be made on the price series to use throughout the PFM. Options include relying on observed prices from transactions or applying a free-market price. In both cases, further decisions include the level of commodity classification, \( c \), for which prices are used; the timeframe applied, \( t \); flow \( f \), i.e., focusing on only imports or exports, or both; reporting, \( r \), and trading partner, \( p \); or units of measurement, \( u \). We look at each in turn.

Using observed prices has an advantage of employing the same data source, yet, by doing so, any mispricing present can be integrated in the price filter, hence making price filter vulnerable to bias. Free-market price remedies this drawback, yet it suffers from being applicable only to the commodities for which a clear, commonly accepted market exists, and can be easily identifiable. We propose to use as much as possible independent, free-market prices.

In line with adjustments above, we propose to use a price at the most detailed product classification level possible, potentially enhancing it further with product descriptions. This will bring on board discussions on varying product characteristics (see Case study 3) and will inherently require heavy involvement of commodity and trade experts.

**Case study 3. Calculating benchmark prices for gold**

Gold is identified as a commodity with variations in its characteristic, the contents of gold, or other metals. In their application of PFM to gold imports to Switzerland, Carbonnier and Mehrotra (2020) use free market price to determine the arm’s length price range, concretely the London Bullion Market Association (LBMA)’s daily spot price series for refined gold bars. As they note, according to the Metals Focus Gold Silver Dore Service database, gold doré bars produced and traded internally can contain between 2-95 per cent pure gold by weight, silver (ranging between 0-92% by weight) and other impurities (up to 5 per cent by weight). Consequently, they use the country-level gold and silver content in doré produced, and use formulas to calculate a maximum and minimum benchmark prices:

\[
Maximum \ benchmark \ price = (daily \ price \ of \ gold \ * \ maximum \ gold \ content \ in \ doré) + (price \ of \ silver \ * \ minimum \ silver \ content)
\]
\[
Minimum \ benchmark \ price = (daily \ price \ of \ silver \ * \ maximum \ silver \ content \ in \ doré) + (price \ of \ gold \ * \ minimum \ gold \ content)
\]
Time dimension, furthermore, is important from two perspectives: first, which timeframe to use in the sense of including only the current price, or rather incorporate a longer period, to account for some of the variations in the market. Second, whether to use the rolling-value, such as moving average, or simply use one fixed value for entire studied period. We propose to avoid using a fixed value for a longer period yet do base the central price on multiple-period observations. To encompass this, a moving-average for a shorter period, e.g., three days, is proposed (see Case study 4). Again, experts' inputs are relevant also at this point.

Whenever possible, specific observations for both reporting and partner companies may be of valuable input to determine whether the mispricing refers to free-market circumstances, or is the phenomenon of transfer pricing included. In such instances, using a common identifier is required to link a company from transactions database to either structural business or relevant MNEs databases.

Seeking expert knowledge (including those of trading partner abroad) is helpful also in cases where specific market conditions impact the observed and true prices on the market, such as long-term contracts. A particular market condition is also the prevalence (or domination) of trade flows by the use of intermediary entities located in low-tax jurisdictions (e.g., tax havens), such as observed in Brazil as high reliance on triangular operations through offshore intermediary entities located in low-tax jurisdictions (see Error! Reference source not found. for the concept and Case study 4 for application of PFM).

Second, define the range of the price filter, be it either as clearly defining lower- and upper-bound price, or defining an amount of variation around central price from first step. There are two main approaches to defining the price filter. The first one is the use of statistical filter and is linked to using transactions-based prices in also determining the central price; and the second, the use of free-market prices and related range.

With reference to statistical price filters, using inter-quartile range (IQR) assumes that the range between first and third quartiles (25th and 75th percentile, respectively) for a particular case represents its arm’s length price range. Corresponding price filter, lower-bound price (LP) and upper-bound price (UP) are determined as:

\[
\text{price filter}_{f,c,r,p,t,u} = \text{IQR}_{f,c,r,p,t,u} \quad \text{Equation (15)}
\]

\[
\text{LP}_{f,c,r,p,t,u} = 25\text{th Percentile}_{f,c,r,p,t,u} \quad \text{Equation (16)}
\]

\[
\text{UP}_{f,c,r,p,t,u} = 75\text{th Percentile}_{f,c,r,p,t,u} \quad \text{Equation (17)}
\]

Other percentiles can also be used to define lower and upper bounds of the price filter. These deviations from the IQR, however, would need to be supported by expert’s inputs. According to statistical price filter, transaction prices lower than the price filter’s lower bound (1st quartile if IQR is used) are marked as abnormal low prices; prices above price filter’s upper bound (at 3rd quartile in IQR) represent abnormal high prices; and the transaction prices within the price filter are referred to as normal prices.
Using the free-market price filter, an actual transaction price is compared to the free-market price (or its moving average as per discussion above in determining the central price) for a particular commodity, where the arm’s length is determined by an assumed range of deviation from the central price, \( \alpha \) from equation (14), determining lower- and upper-bound prices as:

\[
LP_{f,c,r,p,t,u} = cp_{f,c,r,p,t,u} - \alpha_{f,c,p,t,u} \\
UP_{f,c,r,p,t,u} = cp_{f,c,r,p,t,u} + \alpha_{f,c,p,t,u}
\]

Equation (18)

Equation (19)

This variation is to account for product specific circumstances, price volatility, contractual terms or other business conditions, transportation costs (if relevant), any political, economic or environmental shocks that may impact the prices of a particular commodity. Again, prices within the price filter’s range are taken to be normally priced, while any prices outside this range are considered abnormal prices. Experts are heavily involved in this step to determine the magnitude of normal price deviations around the central price.

4. Over- and under-pricing

In fourth phase, the amount of over- and under-pricing is determined. As noted above, lower and upper bound prices are used to identify abnormal prices. Undervalued amount refers to the amount (value) of a transaction with price below lower bound price, using quantity (volume) \( Q \) from the individual transaction:

\[
\text{Undervalued amount}_{f,c,r,p,t,u} = Q_{f,c,r,p,t,u} \times \max(0, LP_{f,c,r,p,t,u} - P_{f,c,r,p,t,u})
\]

Equation (20)

Analogously, overvalued amount is represented by:

\[
\text{Overvalued amount}_{f,c,r,p,t,u} = Q_{f,c,r,p,t,u} \times \max(0, P_{f,c,r,p,t,u} - UP_{f,c,r,p,t,u})
\]

Equation (21)

5. Inward and outward IFFs

In final phase, inward and outward IFFs are calculated via aggregation. Again, inward IFFs are overvalued exports and/or undervalued imports; and outward IFFs refer to undervalued exports and/or overvalued imports. Using notations in this section, replacing subscript \( f \) with a superscript of either \( EX \) for exports or \( IM \) for imports, they are defined as:

\[
\text{Inward IFFs}_{c,r,p,t,u} = \text{Overvalued amount}^{EX}_{c,r,p,t,u} + \text{Undervalued amount}^{IM}_{c,r,p,t,u}
\]

Equation (22)

\[
\text{Outward IFFs}_{c,r,p,t,u} = \text{Undervalued amount}^{EX}_{c,r,p,t,u} + \text{Overvalued amount}^{IM}_{c,r,p,t,u}
\]

Equation (23)

Finally, aggregation at national and annual levels is obtained by (assuming \( t \) referred to less-than annual level, e.g., daily frequency and its summation/aggregation therefore refers to an annual value):
InwardIFFs = \sum_{c,r,p,t,u} \text{InwardIFF}_{c,r,p,t,u} \quad \text{Equation (24)}

OutwardIFFs = \sum_{c,r,p,t,u} \text{OutwardIFF}_{c,r,p,t,u} \quad \text{Equation (25)}

Case study 4. Price Filter Method for the Soya Bean exports in Brazil

Amaral and Barcarolo (2020) applied the PFM to Brazilian soya bean exports. In Brazilian market the soya bean price is composed of the commodity future market quoted price and a premium basis, that is paid to the exporters. The soya bean price filter is therefore calculated as:

SOYA BEAN PRICE FILTER = [QUOTED PRICE + PREMIUM BASIS] +/- \alpha (%)

Price filter was statistically estimated using a three-day weighted moving average price, based on the transaction-level data collected by the Customs Bureau. Outlier treatment was applied using IQR before estimating the weighted moving average price.

The case is important also in the refining of the PFM analysis by considering economic substance. Particularly, this refers to observing high-risk transactions in terms of their exposure to BEPS and segregating transactions by country of acquisition into tax havens, privileged regimes, or other jurisdictions (following national regulation). Suspicious abnormally under-priced invoices are presented in the following chart.

Invoice prices at transactions level, by jurisdiction of acquisition and estimated risk exposure to BEPS, 2012-2020

Source: SISCOMEX Customs Database, Amaral and Barcarolo (2020)

The potential tax IFFs were estimated as follows:
Where:

- **Weighted Average Price (t):** daily average price weighted by transaction-level invoice prices and quantity in tons.
- **Weighted Moving Average Price (t):** three-day moving average price weighted by quantity of tax payers (exporters) and by quantity of exports transactions.
- **Price Filter Range (t):** upper and lower bound prices set at the three-day weighted moving average price +/- 1σ (standard deviation).
- **Lower Bound Price (t):** three-day weighted moving average price - 1σ (standard deviation).
- **Total Estimated BEPS-related FF:** the sum of the differences between the lower bound prices and transaction-level invoice prices below the lower bound (potential underinvoiced exports) in the period from date \( t=1 \) to \( t=n \), wherein \( 1 \) represents the first and \( n \) the last day.
- **TIN (t):** quantity of taxpayers (exporters) in a date \( t \).
- **E(t):** quantity of export transactions in a date \( t \).
- **Invoice Price (i):** transaction-level invoice price in a date \( t \).
- **Quantity(i):** weight in tons by transaction-level invoice price in a date \( t \).

Estimated tax-related IFFs on export side amount to just below 1 per cent of total exports, around US$504 million. The authors further note that considering that around 99 per cent of export transactions happen between affiliated entities located in favoured taxation jurisdictions, the price filter for the soya bean trade market (estimated using transaction level trade data by the Customs) are likely biased down due to aggressive tax planning strategies. Applying a free-market rather than statistical price filter is required in such cases to guarantee reliability of the results in further applications of the method.

**Estimated BEPS-related financial flows**

<table>
<thead>
<tr>
<th>country of acquisition</th>
<th>triangular transactions</th>
<th>Incoterm</th>
<th>total exports US$</th>
<th>quantity TON</th>
<th>estimated BEPS-related FFs US$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Art.1° - Tax Haven</td>
<td>Yes</td>
<td>FOB</td>
<td>18.128.478.967</td>
<td>47,964.971</td>
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<tr>
<td>Art.2° - Privileged Tax Regime</td>
<td>Yes</td>
<td>FOB</td>
<td>29.913.890.618</td>
<td>79,024.100</td>
<td>300,401,808</td>
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<tr>
<td>Other jurisdictions</td>
<td>Yes</td>
<td>FOB</td>
<td>5,552,851.496</td>
<td>14,590.957</td>
<td>38,643,608</td>
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<tr>
<td>Other jurisdictions</td>
<td>No</td>
<td>FOB</td>
<td>150,150,582</td>
<td>407,331</td>
<td>2,507,883</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>53,745,171.664</td>
<td>141,987.359</td>
<td>503,851,830</td>
</tr>
</tbody>
</table>

Source: Amaral and Barcarolo (2020)