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A conceptual note on the aggregation of international prices using index numbers

Abstract:
Aggregation of international prices in empirical work is generally based on well known index number formulas. However, a common practice applying such formulas is the use of price indices rather than price levels for which data across countries are rarely available. Numerical calculations of price aggregates are therefore typically not able to fully capture the increasingly important role that low-cost countries play in determining international prices. When only price indices for a tradable group of interest are available the question arises of how to approximate relative price levels across countries to accommodate inflationary impulses and price level differences in a final index number. In the present note, we address this question from both a theoretical and an empirical perspective. We propose a conceptual framework for analysing sources of change in international prices using the Törnqvist price index as the underlying index number formula. Herein, we suggest a calibration method based on purchasing power parities to make a relative price index interpretable as a relative price level. We present an illustrative numerical example based on data from the industry of textiles and wearing apparel. Our findings show that the impact of price level differences (the so-called China effect) is substantial in the computed aggregate of international prices.

Keywords: Aggregation, index numbers, international prices, the China effect

JEL classification: C43, E31

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Sammendrag

Aggregering av internasjonale priser er generelt basert på velkjente indeksformler. Vanlig praksis når slike formler anvendes er imidlertid å basere seg på prisindekser, og ikke prisnivåer, som datagrunnlag. Numeriske beregninger av prisaggregater fanger derfor typisk *ikke* opp alle effektene av den stadig viktigere rolle lavkostland spiller i bestemmelsen av internasjonale priser. Når bare prisindekser er tilgjengelige for en varegruppe aktualiseres spørsmålet hvordan finne et relevant mål på prisnivåforskjeller mellom land, slik at både inflasjonsimpulser *og* prisnivåforskjeller kan fanges opp i et endelig prisaggregat. Vi analyserer denne problemstillingen både fra et teoretisk og et empirisk perspektiv, og foreslår et konseptuelt rammeverk for analyse av ulike kilder til endringer i internasjonale priser med Törnqvist prisindeks som underliggende indeksformel. Herunder foreslår vi en kalibreringsmetode basert på kjøpekraftspariteter, slik at relative prisindekser kan tolkes som relative prisnivåer. Vi presenterer et illustrativt numerisk eksempel med data fra klesindustrien, og viser at bidraget fra prisnivåforskjeller mellom land er betydelig i det beregnede aggregatet for internasjonale priser.

1 Introduction

Aggregation of price data is often needed in empirical economics and is generally based on an index number formula. For instance, analyses of international prices and terms of trade among countries are typically conducted by means of an index number formula to aggregate subsets of international prices on exports and imports, see e.g. Macdonald (2010), Silver (2009, 2010) and Atkinson and Burstein (2008) for some recent examples. As numerous index number formulas with different aggregation properties exist in the literature, practitioners are often faced with the problem of which one of them to use in order to properly answer the price aggregation problem at hand. Index number theory advocates the use of so-called superlative index number formulas, including the Fischer and Törnqvist price index, to account for flexible substitution effects between commodities caused by relative price level changes, see Diewert (1976, 1978). The Laspeyres and Paasche price indices, on the other hand, are index number formulas associated with underlying aggregator functions that cannot accommodate such substitution effects in a final index number.[1]

The appealing aggregation property of superlative price indices is, however, somewhat counterbalanced by the fact that available data for a commodity group of interest usually are price *indices* and not price *levels*, in which case such index number formulas (like any other index number formulas) may not be directly ready for numerical calculations in practice. If a set of available price indices is plugged directly into a superlative price index, say the Törnqvist price index, only inflationary impulses implied by price changes and substitution between products with different price changes are accounted for in the final price aggregate. Hence, when only price indices are available the question arises of how to approximate relative price levels to accomodate inflationary impulses *and* price level differences across products in an index number. That question is potentially of major relevance in empirical work concerned with aggregation of international prices of tradables, which over the last two decades or so have been heavily influenced by significant removal of non-tariff barriers to trade, reduced tariffs and shifts in imports from high-cost to low-cost countries.

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[1] Whereas the Törnqvist price index is associated with the translog cost function as the underlying aggregator function, the Laspeyres price index, for example, relates to the highly restrictive Leontief aggregator function which makes substitution possibilities among commodities impossible, see e.g. Balk (2008).

As one of very few studies, Thomas and Marquez (2009) address the question when modelling US import prices. Based on nominal exchange rates and purchasing power parity adjusted exchange rates from the Penn World Tables[2], Thomas and Marquez (2009) aggregate US international relative price levels by the geometric Paasche price index, which together with aggregate price data for US domestic products – the GDP deflator – are used to solve for aggregate foreign prices in US dollars. Accordingly, Thomas and Marquez' (2009) measure of foreign prices fully captures the increasingly important role that low-cost countries play in determining international prices. However, it does not allow measurement of the effects from inflation and price level differences separetely, only measurement of the total effect on the foreign price measure. Equipped with foreign export price indices, Nickell (2005) proposes an alternative approach when analysing the impact of a changing trade pattern on overall consumer price inflation in the UK. By differencing the geometric Paasche price index (in logs) once and making use of data from the Penn World Tables, Nickell (2005) is able to decompose the growth rate of his foreign price aggregate into two separate and interpretable parts, one consisting of effects from inflationary impulses and one consisting of effects from price level differences across countries. Unfortunately, Nickell (2005) does not describe the operational route necessary to make relative price indices interpretable as relative price levels in his decomposed geometric Paasche price index.

In this conceptual note, we are inspired by both Thomas and Marquez (2009) and Nickell (2005). Similar to these studies, we do not attempt to anchor price level differences among countries in the first place within the classical index number problem of splitting a value change multiplicatively into a price index and a quantity index, see e.g. Balk (2005). Instead, we employ the Törnqvist price index and not the geometric Paasche price index as the underlying index number formula, thereby utilising all information at hand. We provide a decomposition of sources of change in the Törnqvist price index when only price indices of tradables are available, including effects of changes in each price index and effects of levels of each relative price index. Herein, we suggest a calibration method based on purchasing power parities to make a relative price index interpretable as a relative price level across countries. Contrary to the two mentioned studies, we not only focus on the empirical interpretation of the final index number constructed, but also on its

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[2] See Summers and Heston (1991) for an early introduction to the Penn World Tables.

theoretical index number underpinnings or lack thereof. As a numerical example, we use data from the industry of textiles and wearing apparel (henceforth clothing). Our findings show that the deflationary impulses on traded goods prices from the switch of imports from high-cost to low-cost countries – the so-called China effect – is substantial in the computed price aggregate for clothing. We also find some important differences in the computed price aggregate when using the geometric Paasche price index and the Törnqvist price index as the underlying index number formulas within our conceptual framework.

The rest of the note is organised as follows: Section 2 presents relevant index number theory, Section 3 discusses empirical issues, including our decomposition of the Törnqvist price index and our proposed calibration method and Section 4 presents the data and the results of the numerical example. Section 5 concludes.

2 Index number theory

It is well known that the Törnqvist price index is one of several discrete time approximations to the continuous time Divisia price index. As argued by Trivedi (1981) among several others, the Törnqvist price index is the best approximation to the Divisia price index because it makes use of all available information. However, the Törnqvist price index, like any other discrete time price index in the literature, is essentially a so-called bilateral index as it compares prices pertaining to two and only two time periods. The Divisia price index can be viewed as a theoretical rationale for chaining the Törnqvist price index when there are more than two time periods involved in a price comparison.[3]

To clarify matters for our purposes, we first briefly present the Divisia price index for period t relative to a certain base period $t-1$, which then is defined by the line integral

$$(1) \qquad P^{DIV}(t,t-1) \equiv \exp\left\{ \int_{t-1}^{t} \sum\nolimits_{n=1}^{N} s_n(\tau) d \ln p_n(\tau) \right\},$$

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[3] Chaining of index numbers is nothing but a multiple of bilateral indices. That is, at every new period, the previous period is chosen to act as base period, and the period-to-period index numbers are multiplied with each other. The final index number is called a chained index number, see e.g. Balk (2008, p. 122).

where

$$s_n(\tau) \equiv \frac{p_n(\tau) \cdot x_n(\tau)}{\sum_{n=1}^{N} p_n(\tau) \cdot x_n(\tau)}, n = 1, ..., N,$$

is the value share of commodity n at time period τ, see Balk (2008, p. 24). We see that the Divisia price index in (1), as a function of continuous time, takes into account the prices (p_n) and quantities (x_n) of all intermediate periods between t and $t-1$. Hence, the Divisia price index not only depends on the initial and final periods of the time interval considered as is the case with bilateral indices, but depends on the entire time path that the prices and quantities belonging to a specific economic aggregate of interest have taken. The growth rate of the Divisia price index at period t is given by

$$\text{(2)} \qquad \frac{d \ln P^{DIV}(t, t-1)}{dt} = \sum_{n=1}^{N} s_n(t) \frac{d \ln p_n(t)}{dt},$$

and thus equals a weighted average of the growth rates of the prices $p_n(t)$ for $n = 1, ..., N$, see Balk (2008, p. 205) for a simple exposition. Faced with discrete data in empirical work, we observe that the formulas in (1) and (2) are not immediately ready for numerical calculations. This raises the question of how to approximate the line integral in (1) in practice. When only data pertaining to the periods t and $t-1$ are given, the approximation

$$\text{(3)} \qquad P^{DIV}(t, t-1) \approx P^{T}(t, t-1) = \prod_{n=1}^{N} \left(\frac{p_n(t)}{p_n(t-1)} \right)^{\bar{s}_n(t)},$$

where

$$\bar{s}_n(t) \equiv \frac{s_n(t) + s_n(t-1)}{2}, n = 1, ..., N,$$

$0 \leq s_n(h) < 1$ and $\sum_{n=1}^{N} s_n(h) = 1$ for $h = t, t-1$, is known as the Törnqvist price index, which in turn is defined as the geometric mean of the geometric Laspeyres and geometric Paasche price indices, see Balk (2008, p. 72). The Törnqvist price index uses the arithmetic mean of the value shares of the comparison period $s_n(t)$ and the base period $s_n(t-1)$ as weights. The geometric Laspeyres and geometric Paasche price indices, however, apply the base period and comparison period value shares as weights, respectively. Notwithstanding, one is in practice equipped with many more data points than just two in the construction of a final index number, which calls for chaining (3) in some way or another to make use of all available information in each consecutive period. As mentioned in the introduction, usually price *indices* and not price *levels* are available, a feature that complicates the use of (3) as a formula for numerical calculations of price aggregates like the one in this note. We discuss these empirical issues further below in light of our aggregation problem.

3 Empirical issues

Generally, we may write the Törnqvist price index analogous to (3) evaluated in period t when available price data are indices and not levels as

$$P^T(t) = \prod\nolimits_{n=1}^{N} \left(p'_n(t)\right)^{\bar{s}_n(t)}, \tag{4}$$

where $p'_n(t)$ denotes the price index for commodity n in period t. Aggregating price indices by means of (4) directly will only capture inflationary impulses because a price index by construction measures the percentage change in a price relative to a base period. Evidently, we need to implement some proxy for bilateral relative price levels in our price aggregate, without too much loss of rigorous index number theory, to accommodate measurement of both inflationary impulses and price level differences across countries. We suggest a calibration method that builds on Thomas and Marquez (2009) in the calculation of relative price levels.

The first step of our calibration method involves constructing calibration coefficients for each country m in a given base period, labelled λ_m, by means of the formula[4]

$$\lambda_m = \frac{E_{m,\$}}{E^{PPP}_{m,\$}}, \tag{5}$$

where $E_{m,\$}$ is the bilateral spot dollar exchange rate relative to the currency of country m and $E^{PPP}_{m,\$}$ is the purchasing power parity adjusted exchange rate provided by the Penn World Tables[5], both evaluated in the base period for our purposes.

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[4] In what follows, commodity n is replaced by country m. The aggregation problem in (4) then becomes weigthing together price indices $p'_m(t)$ of a tradable group of interest from country m using value shares of imports $s_m(t)$ as weights.

[5] See Heston *et al.* (2011).

These purchasing power parity adjusted exchange rates are weigthed averages of the prices of the mth country relative to US prices, employing production levels of the mth country as weights. As pointed out by Thomas and Marquez (2009), relative price levels measured by (5) are unitless and easy to interpret. For instance, a λ_m equal to 0.5 would imply that the price level of the commodity group in the US is 50 per cent of that in country m.

The second step of our calibration method involves multiplying the calibration coefficients with the corresponding price indices underlying (4). The calibrated price indices − which are to be interpreted as relative price levels − will thus equal the relative price levels calculated from (5) in the base period, where the price indices are set equal to unity.

We sum up our calibration method by rewriting (4) as

$$P^T(t) = \prod_{m=1}^{M} \left(\lambda_m \cdot p'_m(t)\right)^{\bar{s}_m(t)} . \tag{6}$$

Applying (6) to our aggregation problem will, as in Thomas and Marquez (2009), produce an aggregate of foreign prices that measures the total price effects of the shift in imports towards low-cost-countries.

We build on Nickell (2005) in order to decompose the total price effects into inflationary impulses and price level differences across countries. In the following exposition, we only consider two countries ($m = 1, 2$), to simplify matters without loss of generality. Our decomposition of the Törnqvist price index first involves taking natural logarithms of (4) (with m replacing n) and differencing once to obtain

$$\begin{aligned} \Delta \ln P^T(t) &= \ln P^T(t) - \ln P^T(t-1) \\ &= \bar{s}_1(t) \cdot \ln p'_1(t) + \bar{s}_2(t) \cdot \ln p'_2(t) \\ &\quad -\bar{s}_1(t-1) \cdot \ln p'_1(t-1) - \bar{s}_2(t-1) \cdot \ln p'_2(t-1), \end{aligned} \tag{7}$$

where Δ indicates the first difference operator. Then, adding and subtracting $\bar{s}_1(t) \cdot \ln p'_1(t-1)$ and $\bar{s}_2(t) \cdot \ln p'_2(t-1)$ to the right hand side of (7), making use of the adding up condition of the value shares of imports and collecting terms, we get

$$\begin{aligned} \Delta \ln P^T(t) &= \bar{s}_1(t) \cdot \Delta \ln p'_1(t) + \bar{s}_2(t) \cdot \Delta \ln p'_2(t) \\ &\quad +\Delta \bar{s}_1(t) \cdot \left(\ln p'_1(t-1) - \ln p'_2(t-1)\right) . \end{aligned} \tag{8}$$

We may see the growth rate of the Törnqvist price index as a discrete approximation to the growth rate of the Divisia price index in (2). However, whereas the first line of (8) is easy to interpret as the weighted average of the growth rates of the individual price indices, the second line is not easily interpretable as price indices and not price levels constitute the difference in the last parenthesis. The two price indices are equal in a base period (typically 1 or 100), and thus provide no information on bilateral relative price levels as such, which is necessary to interpret the second line as a price level effect. Consequently, (8) is not directly compatible with numerical calculations in empirical contexts like the one in this note. That said, we may nevertheless employ (8) by once again using the calibration method described above to make relative price indices interpretable as relative price levels.

Formally, we show the calibration method in this context by augmenting (8) with calibration coefficients from (5), such that

$$\begin{aligned} \Delta \ln P^T(t) &= \bar{s}_1(t) \cdot \Delta \ln p_1'(t) + \bar{s}_2(t) \cdot \Delta \ln p_2'(t) \\ &\quad + \Delta \bar{s}_1(t) \cdot (\ln(\lambda_1 \cdot p_1'(t-1)) - \ln(\lambda_2 \cdot p_2'(t-1))), \end{aligned} \tag{9}$$

where λ_2 equals unity because country 2 is chosen as the numeraire country. The calibrated relative price indices equal the calibration coefficients in the base period and from then on develop according to the actual development of the levels of the respective price indices.[6]

By calculating $\Delta \ln P^T(t)$ in this way, we allow for separate measurement of inflationary impulses and price level differences among countries included in the price aggregate. The two first terms on the right hand side of (9) show that increasing price inflation from each of the two countries contributes to increasing inflationary impulses in the price aggregate. The larger the price increase and the larger the import share, the larger is the inflationary impulse in $\Delta \ln P^T(t)$. The last term on the right hand side of (9) constitutes the total effect of the price level differences, which we in the introduction labelled the China effect. If the import share is changing in favour of a low-cost country, the last term becomes negative. The larger the change in the import share and the larger the difference in price levels, the larger is the deflationary impulse in $\Delta \ln P^T(t)$. Notice that the China effect is zero with

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[6] As the inflation terms in (9) are expressed as logarithmic changes of price indices, calibrating the price indices has no impact here.

constant import shares. Although the bilateral distribution of the China effect can be sensitive to the choice of numeraire country, the size of the aggregated China effect calculated from (9) is not. As (9) is based on comparisons of each of the two consecutive time periods over the entire time interval of data points, we argue that (9) is one way of chaining the bilateral Törnqvist price index in our context. We set P^T equal to unity in the base period and let the price index level from then on be determined consecutively by the calculated growth rates from (9).

For comparison, we also utilise Nickell's (2005) decomposition of the geometric Paasche price index using the same data set. In the case of only two countries, using our notation and our suggested calibration method, we write Nickell's (2005) decomposed formula[7] as

$$\begin{aligned} (10) \qquad \Delta \ln P^P(t) &= s_1(t) \cdot \Delta \ln p_1'(t) + s_2(t) \cdot \Delta \ln p_2'(t) \\ &\quad + \Delta s_1(t) \cdot (\ln(\lambda_1 \cdot p_1'(t)) - \ln(\lambda_2 \cdot p_2'(t))), \end{aligned}$$

where $s_1(t)$ and $s_2(t)$ are the comparison period value shares of imports from country 1 and 2, respectively. We see that (9) and (10) differ with respect to weights attached to both the inflation terms and the price level terms. This is potentially important as illustrated in our numerical example. Generally, both the inflation terms and the price level terms in (9) and (10) depend on the magnitude of the value shares in each period and on the direction of changes in the value shares from one period to another. Whereas the weights in (9) tend to smooth such changes by the arithmetic mean of the value shares, the weights in (10) do not. Finally, we notice that the dating of the price level differences also differs in (9) and (10), which will also affect the computed price aggregate.

4 A numerical example

In this section, we illustrate the conceptual framework described above by a numerical example based on data on foreign prices faced by Norwegian importers of clothing. The motivation of our example follows from the fact that low consumer price inflation observed over several years in Norway coincides well with a simultaneous fall in import prices on clothing. The development in import prices on clothing

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[7] Equation (1) in Nickell (2005).

over the last two decades or so should be viewed in light of massive trade liberalisation, which has increased the imports of clothing from China and other low-cost countries at the expense of imports from high-cost countries, the euro area in particular. The significant shift in trade pattern has contributed to reduced purchasing prices for Norwegian importers of clothing, and thereby also the consumer prices on clothing.

The underlying data are quarterly price indices (measured in foreign currencies) from Norway's main trading partners: the euro area (eu), the United Kingdom (uk), Denmark (dk), Sweden (sw), Hong Kong (hk) and China (ch), of which China stands out as a low-cost country.[8] Together these countries covered about 75 per cent of Norwegian imports of clothing as an average over the sample period $1997-2007$.[9] Certainly, the share in imports from China has increased steadily from a negliable level since 1986, the starting year of the so-called Uruguay Round Agreement of gradually dismantling the international system of import quotas in the clothing industry. However, reliable data on prices of clothing are only available for China from 1997, yet sufficient for illustrative purposes in our numerical example. Figure 1 displays country specific export price indices ($p'_m(t)$) for clothing, measured in a common currency, over the sample period.[10]

Overall, we see that the export prices for the Scandinavian countries and the euro area increased somewhat, whereas the export prices for the other countries decreased somewhat over the entire sample period. We also observe that the export prices in general increased during the first 3 to 4 years of the sample period. From then on the export prices levelled out or dropped somewhat due to increased price competition from increased presence of low-cost countries on international markets following trade liberalisation and China joining the WTO in 2001. The distinct raise and fall of the China and Hong Kong price indices during the first five years of the 2000s are dominated by the corresponding movements of the USD as these countries' exchange rates were pegged to the USD in that period. Noticeably, the

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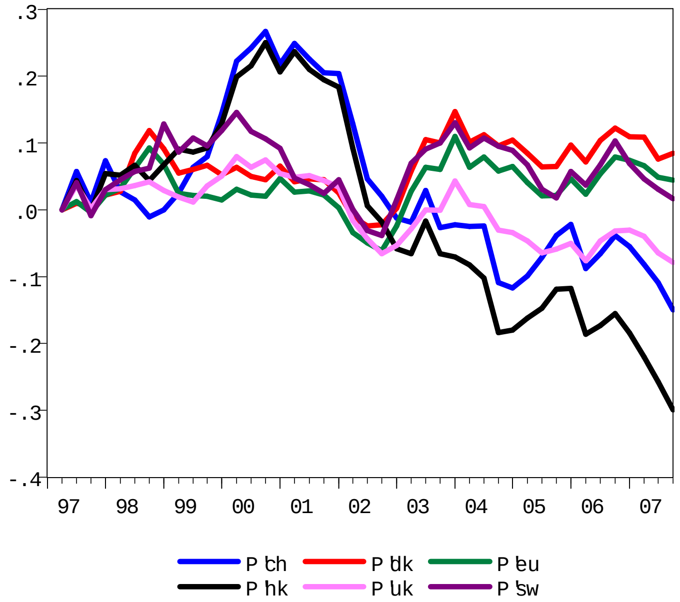
[8] See the Appendix for details about the data definitions and sources.

[9] The rest of exports of clothing to Norway come from countries with relatively small import shares, except Bangladesh and Turkey with import shares of about 8 and 10 per cent, respectively, towards the end of the sample period. They are left out of the numerical example due to lack of relevant price data. Because the euro area is treated as one country, we abstract from any import substitution from high-cost to low-cost countries within the monetary union.

[10] We use the bilateral exchange rates between Norway and country m to measure $p'_m(t)$ in a common currency, $m = eu, uk, dk, sw, hk, ch$. Source: Central Bank of Norway.

Figure 1: Country specific export price indices (in logs) for clothing



fall in the China price index stops in 2005 when China abandoned the USD peg. Figure 2 displays country specific value shares of imports ($s_m(t)$) of clothing over the sample period.[11]

We see that the import share from China increased remarkably from around 25 per cent in 1997 to more than 60 per cent in 2007. The import share from the euro area fell likewise from around 40 per cent in 1997 to around 20 per cent in 2007. Whereas the import share from Sweden was relatively stable around 5 per cent, the import shares from United Kingdom and Denmark dropped by nearly 10 percentage points each during the sample period. Hong Kong also experienced a lower import share by 5 percentage points during the period 1997 – 2007. Overall, the shift in imports towards the low-cost country China was evident throughout the sample period, but was intensified somewhat from 2001 when China joined the WTO. Table 1 shows the calculated international relative price levels (λ_m) in 1997 based on (5).[12]

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[11] The value shares of imports in Figure 2 sum to unity in each period.

[12] The calibration coefficient λ_m in (5) expresses the relative price level of country m relative to the US as the data from the Penn World Tables are denominated in US dollars. As the US is not included in our numerical example, we choose the euro area as numeraire country among Norways'

Figure 2: Country specific value shares of imports of clothing

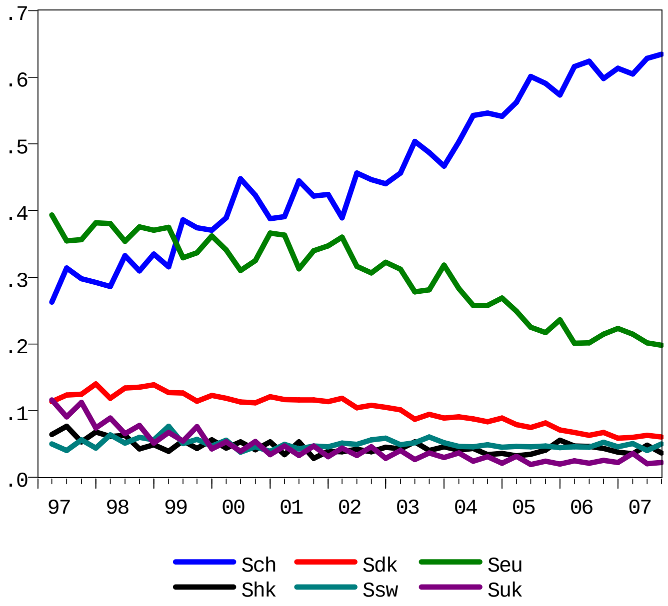

Table 1: Relative price levels (λ_m). 1997

dk	*sw*	*hk*	*uk*	*eu*	*ch*
1.33	1.24	1.13	1.04	1.00	0.31

Source: The Penn World Tables,
Heston *et al.* (2011)

As the euro area is chosen as numeraire country, λ_{eu} equals unity. We see that $\lambda_{ch} = 0.31$, which means that the price level in China was 31 per cent of that in the euro area in 1997. The data provided by the Penn World Tables are based on a large and highly comparable number of products (at the GDP level) across countries. Hence, we recognise that the figures in Table 1 are good proxies for our purposes to the extent that relative price levels on clothing across countries were similar to relative price levels of the commodity aggregate underlying the Penn World Tables in 1997. Figure 3 displays computed price aggregates (P^T in logs) for clothing,

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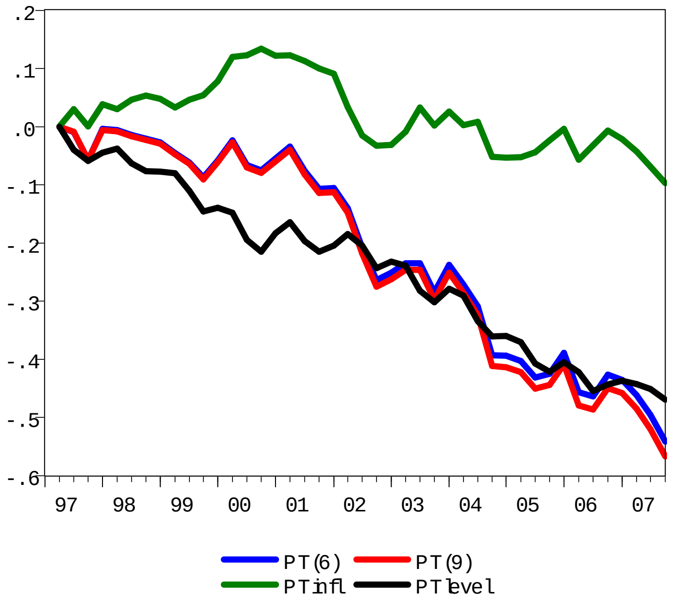
trading partners, and let $\lambda_{m,eu} = \frac{\lambda_m}{\lambda_{eu}}$ express the price level of country m relative to that of the euro area. Furthermore, in the numerical example the calibration coefficients are defined as the inverse of $\lambda_{m,eu}$, where a value of 2 would imply that the price level is twice as high in country m as in the euro area.

measured in a common currency, based on (6) and (9) over the sample period.[13]

Figure 3: Computed price aggregates (P^T in logs) for clothing based on (6) and (9)



Our calculations indicate a substantial fall in the computed price aggregate of 37 per cent during the sample period, which on average implies a yearly decrease in P^T of somewhat less than 3.5 percentage points. We notice that (6) and (9) for practical purposes generate identical price aggregates. The discrepancy between the two aggregates' growth rates is only 0.3 percentage points at the most. Likewise, the average percentage point difference between the two aggregates' growth rates is as small as 0.06 over the sample period. Our calculations further indicate that the price level effects of the shift in imports from high-cost to low-cost countries – the China effect (P^T_{level}) – on average have pushed down price impulses faced by Norwegian importers of clothing by around 3 percentage points each year since 1997. We also observe that the deflationary impulses from the China effect alongside trade liberalisation have dominated the inflationary impulses ($P^T_{\inf l}$) throughout the entire

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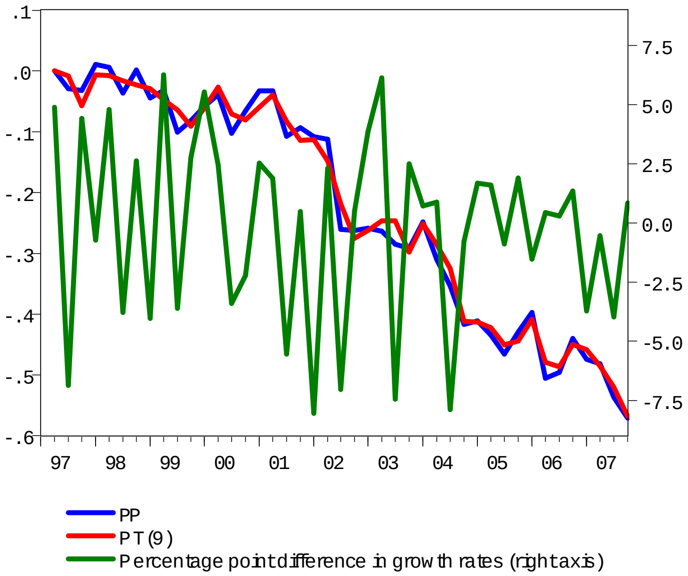
[13] To cope with base period dependency the price indices in (6), (9) and (10) are computed by relating the calculated indices values at any given period to the values in the first quarter of the same year rather than to a fixed base period.

sample period. Interestingly, the inflationary impulses turned negative in 2002 in the wake of China joining the WTO.

We end our numerical example by comparing price aggregates generated from the geometric Paasche price index and the Törnqvist price index as the underlying index number formulas. Figure 4 displays computed price aggregates (P^T and P^P both in logs) for clothing, measured in a common currency, based on (9) and (10) over the sample period.

Figure 4: Computed price aggregates (P^T and P^P both in logs) for clothing based on (9) and (10)



As expected, the two index number formulas produce almost identical price falls in the computed price aggregates during the sample period. Apparently though, the two aggregates differ with respect to the sign and magnitude of growth rates for quite many periods. A closer look reveals that the respective growth rates of the two aggregates, which at the most differ with as much as 8 percentage points (see Figure 4, right axis), have different sign in 16 out of 43 quarters in total (or 37 per cent). The average (absolute) percentage point difference between the two aggregates' growth rates is as large as 3.15 over the sample period. We conclude that the two index number formulas (9) and (10) generate significant differences in the case of our data set.

5 Conclusions

Understanding the impact of the general shift in trade pattern from high-cost countries to low cost-countries on international prices has long been of interest among economists. However, analysis on international prices in empirical work has typically been based on price aggregates computed from well known index number formulas with price indices and not price levels as the underlying data. Consequently, price aggregates reported in the literature often fail to fully capture the increasingly important role that emerging countries with low production costs play in determining international prices.

In this conceptual note, we address the question of how to approximate relative price levels across countries to accommodate inflationary impulses *and* price level differences in a computed price aggregate based on price indices for a tradable group of interest. We suggest a methodology for analysing sources of change in international prices using the Törnqvist price index as the underlying index number formula and propose a calibration method based on purchasing power parities to interpret relative price indices as relative price levels across countries.

We illustrate our methodology by means of a numerical example using data from the clothing industry, which has undergone a tremendous shift in trade pattern towards low-cost countries following the gradual removal of tariffs and non-tariff barriers to trade since the mid 1980s. According to our calculations, the so-called China effect – the deflationary impulses on traded goods prices from price level differences across countries – has been substantial during the sample period. We also find some important differences in the computed price aggregate when comparing the geometric Paasche price index and the Törnqvist price index as the underlying index number formulas within our methodology. Such differences may have some important implications in econometric work, for instance in the quantification of a pricing-to-market model where foreign prices are among the variables explaining import prices.

While our aggregation approach has a nice intuitive appeal, it may lack some rigourous index number theory foundation as price level differences across countries are approximated and not deeply rooted within the classical index number problem in the first place. We believe though that our conceptual framework, given available data in practice, is a good empirical approximation to the classical index number problem and well suited for aggregation problems like the one discussed here.

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Appendix

p'_{ch}: Producer price index of clothing for China, measured in the Chinese currency. Source: Reuters EcoWin.

p'_{eu}: Producer price index of clothing for the euro area, measured in EURO. Source: Reuters EcoWin.

p'_{uk}: Export price index of clothing for the United Kingdom, measured in the UK currency. Source: National statistics online, http://www.statistics.gov.uk/statbase/.

p'_{sw}: Export price index of clothing for Sweden, measured in the Swedish currency. Source: National statistics online, http://www.ssd.scb.se/databaser/.

p'_{dk}: Industrial output price index of clothing for Denmark, measured in the Danish currency. Source: Reuters EcoWin.

p'_{hk}: Producer price index of clothing for Hong Kong, measured in the Hong Kong currency. Source: Reuters EcoWin.

s_m: Value shares of imports of clothing from country m $(m = eu, uk, dk, sw, hk, ch)$. Source: Statistics Norway, the Foreign Trade Statistics.

$E_{m,\$}$: Bilateral spot dollar exchange rate relative to the currency of country m $(m = eu, uk, dk, sw, hk, ch)$. Source: The Penn World Tables, Heston *et al.* (2011).

$E^{PPP}_{m,\$}$: Purchasing power parity adjusted exchange rate for country m relative to the US $(m = eu, uk, dk, sw, hk, ch)$. Source: The Penn World Tables, Heston *et al.* (2011).