January 2014

Calculating the real return of the Norwegian Government Pension Fund Global by alternative measures of the deflator

by

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Abstract

According to the present guidelines for fiscal policy, the use of oil revenues in the Norwegian economy should over time equal the expected *real* return on the Government Pension Fund Global (GPFG). An important empirical question is therefore how to measure the *real* return, taking into account that the aim of the investment strategy of the GPFG is to maximise the purchasing power with respect to future Norwegian imports. In this paper, we present estimates of average annual *real* return of the GPFG over the sample period running from 1998 to 2012 based on alternative measures of the deflator. We find that the choice of international price measure, weighting scheme and method of aggregation generally is of major importance for the measure of the deflator, and thereby for the estimate of the *real* return. Two major factors providing low estimates of inflation and, thus, high real return, are GPFG weights dominated by western, low inflation countries, and export prices growing relatively slow, possibly due to strong international competition. Applying a method of aggregation tailored to also capture the deflationary effects of Norwegian imports increasingly originating from low cost countries (known as the China effect), reduces the estimate of inflation by close to one percentage point. We present estimates of average annual *real* return of the GPFG ranging from 2.3 to 3.3 per cent, and up to 4.5 per cent including the China effect. The present practice of calculating the deflator delivers an estimate of average annual *real* return which is close to the middle of this range.

Keywords: Government Pension Fond Global, Real return, Deflators, Index numbers
JEL classification: C43, E31, F14
Acknowledgements: We are grateful to the Norwegian Ministry of Finance for financial support and to Vibeke H. Bakken, Thomas von Brasch, Øystein Børsum, Ådne Cappelen, Tom Fearnley, Bjørn Geir From, Pål Haugerud and participants at workshops held at the Ministry of Finance on the 12th of December 2013 and at Statistics Norway on the 6th of February 2014 for helpful comments and suggestions. The usual disclaimer applies.

1. Introduction[1]

According to the present guidelines for fiscal policy, the use of oil revenues in the Norwegian economy should over time correspond to the expected *real* return on the Government Pension Fund Global (henceforth GPFG), estimated at 4 per cent when the fiscal policy rule was implemented in March 2001.[2] An important purpose of adapting spending over the state budget in line with the expected real return is to ensure that the capital of the GPFG is not drained over time. The real return of the GPFG is defined as nominal return on the financial assets adjusted for inflation, the latter being the deflator of the GPFG. Thus, the question arises of what is the (most) relevant measure of the deflator, and thereby of the *real* return, taking into account that the aim of the investment strategy of the GPFG is to maximise the purchasing power with respect to future Norwegian imports.[3] In this paper, we present estimates of the *real* return[4] of the GPFG based on given figures of nominal return and alternative measures of the deflator, using combinations of different international price measures, weighting schemes and methods of aggregation.

The fact that the real return shall finance future imports of goods and services to Norway dictates the use of international prices when calculating different measures of the deflator of the GPFG. The deflator currently used for the calculation of the real return is based on consumer price indices (henceforth CPI) of a number of Norwegian (potential) trading partners. However, the prices of goods and services faced by Norwegian importers may differ significantly, both in the short and long term, from the consumer prices, which inter alia include country specific trade margins, excise taxes and value added taxes. Also, the composition of goods and services included in a country's CPI will generally not be the same as the composition of goods and services exported to Norway. It is therefore of interest to use international export prices in the calculations of the deflator of the GPFG. For comparison, we also introduce the GDP deflator (of Norway's trading partners), which is a commonly used, although very broad measure of inflation.

When international prices are aggregated to compute a deflator of the GPFG, we must also decide which countries to include in the weighting scheme. The current practice is that the CPI's are weighted by the investment share of each of the countries included in the benchmark index for equities and fixed income of the GPFG. In practice, however, the import pattern deviates considerably from the investment pattern. One obvious alternative is therefore to use Norwegian import shares as weights,

1 Section 1 may be viewed as a self contained, short version of this paper.
2 See Report No. 29 (2000-2001) to the Storting.
3 See e.g. Report No. 15 (2010-2011) to the Storting.

which reflect the countries Norway actually imports goods and services from. We may also argue that, in order to keep the purchasing power of the GPFG constant, the relevant deflator should reflect prices of future trading partners and not prices of present trading partners. An alternative to import weights as a representation of future trading patterns could be the distribution of global production as measured by GDP, assuming that a country's share of global trade will approach its share of global GDP in the long run. GDP shares would mirror import weights in the long term in a stylized world characterized by perfectly competitive markets without trading costs and comparative advantages.[5] In any case, introducing weights deviating from the GPFG weights adds a complicating element in the calculations of the GPFG deflator, namely exchange rate risk following from exchange rate fluctuations, see e.g. Børsum (2011). The definition of the present deflator implies a perfect match between the currency allocation in the benchmark index for equities and fixed income and the currency composition of consumption (imports) so that converting revenues from the GPFG to consumption does not involve any foreign exchange transactions. However, for all alternative weighting schemes, the countries of investment (and/or their weights) will deviate from the countries of imports to some extent. Thus, changes in exchange rates between GPFG countries and other countries subject to Norwegian imports affect the purchasing power of the fund, also in the long run if deviations from international purchasing power parity in tradable goods are present. In practice, important economies and trading partners of Norway do not satisfy the requirements for GPFG investments. Most notably China, with a weight of around 10 per cent of total imports of Norway and of world GDP in 2012, is not included in the benchmark index of the GPFG in our sample period.[6]

The method of aggregation will generally also matter for the measures of the deflator. Analyses of international prices and terms of trade among countries are typically conducted by means of well known index number formulas in order to aggregate subsets of prices on exports and imports, see e.g. Macdonald (2010), Silver (2009, 2010) and Atkeson and Burstein (2008) for some recent examples. We refer to index number theory and use the Törnqvist price index as the underlying aggregator formula in our empirical case, see e.g. Diewert (1976, 1978). The Törnqvist price index is defined by the geometric mean of the geometric Laspeyres and Paasche price indices, and is preferable due to its property of being a good approximation to the continuous time Divisia price index and the true cost of living index in a world of free trade, see e.g. ILO (2005). We calculate measures of the deflator of the

[4] We do not take into account annual management costs of the fund, averaging 0.09 per cent from 1998 to 2012, see NBIM (2013).

[5] This would imply that Norway imports from all countries in the world, and according to each country's share of global production. No trading costs imply no bias towards trading with neighbouring countries. Absence of comparative advantages implies that small countries do not have a higher share of trade relative to the size of their economy than larger countries.

[6] While Chinese stocks listed on the Hong Kong Stock Exchange (quoted in HKD) are part of the Fund's benchmark index, stocks listed in mainland China, more exactly Shanghai and Shenzhen Stock Exchanges, are currently not included in the benchmark index.

GPFG using both the geometric Laspeyres, which the current practice is consistent with, and Paasche price indices in addition to the Törnqvist price index to shed light on the substitution bias in our empirical context. Aggregation of international prices by means of the Törnqvist price index may, however, be vulnerable to biased results with respect to a true cost of living index as the quantity of tradable goods between countries over the last two decades has been heavily influenced by trade liberalisation. The so-called China effect in the empirical literature, analysing how gradual removal of trade barriers and increased integration of low cost countries into the world trade have put downward pressure on inflation, is likely to be important when calculating measures of the deflator of the GPFG over the last 15 years. Inspired by Nickell (2005), Pain *et al.* (2006), Collie (2008), Wheeler (2008) and Benedictow and Boug (2013) among others, we apply a method of aggregation deviating from traditional index number theory and calculate measures of the deflator by means of the geometric mean of price *levels* to shed light on the magnitude of the China effect in our empirical case.

The numerical measures of the deflator, and thereby of the real return of the GPFG, are based on data running from 1998 to 2012. We pay particular attention to measures of the deflator based on CPI's and GPFG weights, CPI's and import weights, CPI's and GDP weights, GDP deflators and GDP weights and export prices and import weights, all of which are based on the Törnqvist price index and measured in corresponding currency baskets and in NOK. As a comparison, we also include the import deflator of goods and services from the Norwegian national accounts among the alternative measures of the deflator of the GPFG. Generally, we find that the alternative measures of international prices, weighting schemes, index number formulas and currency of measurement all have significant impact on the calculated deflator. Applying yearly data, our calculations indicate that the deflator based on CPI's and GDP weights exhibits the highest average annual inflation over the sample period at 2.9 per cent, whereas the deflator based on export prices and import weights exhibits the lowest average annual inflation of 1.4 per cent, both measured in corresponding currency baskets. When measured in NOK the respective figures are 1.4 and 0.5 per cent. The deflator based on CPI's and GPFG weights delivers average annual inflation close to the middle of the range of the estimates of inflation. That the deflator based on CPI's and GDP weights delivers the highest inflation can mainly be explained by the fact that a number of high inflation countries, Russia and China in particular, are included in the weighting scheme. Similarly, the deflator based on export prices and import weights exhibits the lowest inflation because export prices have increased relatively slow, possibly due to strong competition in international markets.

Applying the method of aggregation tailored to also capture the China effect to the deflator based on export prices and import weights, lowers the estimate of average annual inflation by just above one percentage point, to 0.3 per cent and to –0.6 per cent when measured in the corresponding currency basket and in NOK, respectively. The China effect is thus of major importance in our empirical case, to the extent that purchasing power parity adjusted GDP relative price levels are good proxies to the relative price levels on tradable goods. By way of contrast, the comparable figures delivered by the import deflator from the Norwegian national accounts are 2.6 and 1.5 per cent. Although the import deflator in principle captures the China effect through the use of unit prices of homogenous products across countries, the China effect may in practice be underestimated, and thus inflation be overestimated, because product quality differences following the switch from high to low cost countries are not properly accounted for in the computation of the import deflator.

We also find that measuring the deflator in a currency basket instead of NOK generally reduces volatility, as fluctuations of bilateral exchange rates to some extent offset each other. At the same time measured inflation increases considerably as the NOK has appreciated against the different currency baskets over the sample period. We notice, however, that the different measures of *real* return of the GPFG are not affected by the currency of measurement, as currency conversion of nominal return and the deflator cancel each other out. We present estimates of average annual *real* return of the GPFG ranging from 2.3 to 3.3 per cent, and up to 4.5 per cent when the China effect is also included in the measure of the deflator. The present practice of calculating the deflator based on CPI's and GPFG weights delivers an estimate of average annual *real* return which is close to the middle of this range.

The rest of the paper is organised as follows: Section 2 formalises the aggregation problem, Section 3 discusses data applied in the numerical calculations, Section 4 presents measures of the deflator of the GPFG and Section 5 introduces nominal return and discusses estimates of real return. Section 6 concludes.

2. The aggregation problem

First, we illustrate the aggregation problem by means of the Fisher equation and a simple example involving two countries. Second, we present the index number formulas applied in this paper together with the current practice of calculating the deflator of the GPFG. Finally, we formalise the China effect by introducing price *levels* instead of price *relatives*, which are the basis for standard index number formulas, into the aggregation problem.

2.1 Definition of real return

The Fisher equation generally states that the rate of nominal return of a financial asset of a particular country (approximately) equals the (expected) rate of real return plus the (expected) rate of inflation in that country, see e.g. de Grauwe (1989, p. 181). For our purposes, we consider the Fisher equation *ex* *post* such that the expected rate of real return and inflation are replaced by their *actual* counterparts. Accordingly, we define real return as

$$(1) \qquad 1 + r_j(t) = \frac{1 + i_j(t)}{1 + \pi_j(t)},$$

where $r_j(t)$, $i_j(t)$ and $\pi_j(t)$ denote the rate of real return, nominal return and inflation in country j in period t, respectively.[7] Taking the natural logarithms of (1), we can write $r_j(t) \approx i_j(t) - \pi_j(t)$, such that the rate of real return is approximately equal to the difference between the rate of nominal return and inflation.[8]

Now, to illustrate our aggregation problem, we consider a simple example of two countries, say the euro area and the United States. Let $\alpha_{€}(t)$ and $\alpha_{\$}(t)$ denote the euro area and the US shares of the investments of the GPFG in period t, $i_{€}(t)$ and $i_{\$}(t)$ denote the euro area and the US rate of nominal return on financial assets in period t and $e_j(t)$ denote the growth rate of the euro measured in currency j = €,\$ in period t.[9] Furthermore, let $\beta_{€}(t)$ and $\beta_{\$}(t)$ denote the euro area and the US shares of Norwegian imports of goods and services in period t and $\pi_{€}(t)$ and $\pi_{\$}(t)$ denote the euro area and the US rate of inflation in period t. Applying (1), the aggregate rate of real return of the GPFG measured in euro in period t, $r_{€}(t)$, is then given by

$$(2) \qquad 1 + r_{€}(t) = \frac{\prod_j [(1 + i_j(t)) \cdot (1 + e_j(t))]^{\alpha_j(t)}}{\prod_j [(1 + \pi_j(t)) \cdot (1 + e_j(t))]^{\beta_j(t)}}, j = €,\$,$$

where the nominator and the denominator of (2) are defined as geometric averages of the rate of nominal return and inflation in the euro area and the United States in period t, respectively, both measured in euro. Again, taking the natural logarithms of (2), we get

$$(3) \qquad r_{€}(t) \approx \alpha_{€}(t)i_{€}(t) + (1 - \alpha_{€}(t))(i_{\$}(t) + e_{\$}(t)) - \beta_{€}(t)\pi_{€}(t) - (1 - \beta_{€}(t))(\pi_{\$}(t) + e_{\$}(t)),$$

and the rate of real return or the real purchasing power of the GPFG (measured in euro) generally depends on both nominal returns in the financial markets, $i_{€}(t)$ and $i_{\$}(t)$, the inflation rates, $\pi_{€}(t)$ and $\pi_{\$}(t)$, the country allocations of the investment portfolio and the Norwegian imports, $\alpha_{€}(t)$ and $\beta_{€}(t)$, and the growth rate of the nominal exchange rate, $e_{\$}(t)$. We see from (3) that the real purchasing power is subject to exchange rate risk (exchange rate fluctuations), relating to the difference between the

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[7] In what follows, $r_j(t)$, $i_j(t)$ and $\pi_j(t)$ are growth rates (g_{xt}) defined as $g_{xt} = (x(t) - x(t-1))/x(t-1)$.

[8] We have utilised the fact that $\ln(1+y) \approx y$ around $y = 0$.

currency allocation in the investment portfolio and the currency composition of imports, if deviations from the uncovered interest parity (UIP) of financial assets and/or the relative purchasing power parity (PPP) of tradable goods are present. However, if both UIP and PPP hold, that is $i_{€}(t) = i_{\$}(t) + e_{\$}(t)$ and $\pi_{€}(t) = \pi_{\$}(t) + e_{\$}(t)$, (3) becomes $r_{€}(t) \approx i_{€}(t) - \pi_{€}(t)$ and the real purchasing power is not subject to any exchange rate risk. If only UIP holds, (3) becomes $r_{€}(t) \approx i_{€}(t) - \beta_{€}(t)\pi_{€}(t) - (1-\beta_{€}(t))(\pi_{\$}(t) + e_{\$}(t))$ and the real purchasing power is subject to exchange rate risk through the geometric average of the inflation rates. Similarly, if only PPP holds, (3) becomes $r_{€}(t) \approx \alpha_{€}(t)i_{€}(t) + (1-\alpha_{€}(t))(i_{\$}(t) + e_{\$}(t)) - \pi_{€}(t)$ and the real purchasing power is subject to exchange rate risk through the geometric average of the nominal returns. Finally, when $\alpha_{€}(t) = \beta_{€}(t)$ (3) becomes $r_{€}(t) \approx \alpha_{€}(t)(i_{€}(t) - \pi_{€}(t)) + (1-\alpha_{€}(t))(i_{\$}(t) - \pi_{\$}(t))$ and the real purchasing power is a weighted average of the real returns in the financial markets with no exchange rate risk involved, neither through the geometric average of the nominal returns nor through the geometric average of the inflation rates.

As mentioned in the introduction, aggregate inflation measured by the current deflator of the GPFG is based on the fixed income and equity weights of the benchmark index. This implies a perfect match between the currency allocation in the benchmark index for equities and fixed income and the currency composition of imports, cf. $\alpha_j(t) = \beta_j(t)$ in (2). It follows that the exchange rate risk is zero per assumption in the current practice of calculating the deflator of the GPFG. One of several considerations of the investment strategy of the GPFG is to protect the purchasing power against exchange rate fluctuations by investing in countries from which Norway imports goods and services.[10] Currently, $\alpha_j(t) \approx \beta_j(t)$ for the euro area at just above 30 per cent. However, for several other important countries there is no close relationship between the investment weights of the benchmark index and the pattern of Norwegian imports. For the US and the UK $\alpha_j(t)$ is 31 and 13 per cent respectively, while $\beta_j(t)$ is just around 5 per cent for both countries. Moreover, for the important trading partners Sweden and Denmark, with $\beta_j(t)$ of 13 and 6 per cent, $\alpha_j(t)$ is just 1-2 per cent. Hence, the overall exchange rate risk may still be substantial. That said, the long investment horizon of the GPFG and the tendency of convergence towards PPP in the long run reduce the exchange rate risk, irrespective of which countries Norway imports goods and services from.[11] Having established our aggregation problem formally, we now turn to the choice of the underlying index number formulas for the calculations of alternative deflators, and thereby estimates of the real return of the GPFG.

[9] We remark that $e_j(t)$ per definition is zero in the case of the euro ($e_{€}(t)$=0) .
[10] See e.g. Report No. 15 (2010-2011) to the Storting.
[11] See e.g. Rogoff (1996), Taylor and Taylor (2004), Sarno (2008) and Sarno and Passari (2011).

2.2 Choice of index number formula

As numerous index number formulas with different aggregation properties exist in the literature, we face the challenge of choosing the one that best answers the price aggregation problem at hand, see e.g. Balk (2008) for a survey. There is a strong connection between the so-called Divisia approach, which is a continuous time approach to index number theory, and economic theory, see e.g. Malmquist (1953), Wold (1953), Jorgenson and Griliches (1967) and Hulten (1973).[12] Because the Divisia price index is defined in continuous time, it is essentially a theoretical concept not immediately ready for numerical calculations with available data measured in discrete time. That said, the clear link with economic theory provides a strong justification for the use of discrete time price index number formulas that best approximate the Divisia price index. Generally speaking, index number theory advocates the use of so-called superlative price index number formulas, including the Fisher, Walsh and Törnqvist price indices, see Diewert (1976, 1978).[13] These superlative price indices typically approximate each other very closely in empirical applications and repeatedly show up as being the best approximations to the Divisia price index, see e.g. Trivedi (1981) and ILO (2005, p. 349). Superlative price indices also provide good approximations to cost of living indices[14], treat prices and quantities in the periods compared symmetrically and are less subject to index number biases than alternatives such as the Laspeyres and Paasche price indices, see e.g. Balk (2008).

For these reasons, we rely on the Törnqvist price index as the underlying index number formula for the calculations of relevant deflators of the GPFG. The Törnqvist price index, P^T, is defined as the geometric mean of the geometric Paasche, P^P, and Laspeyres, P^L, price indices such that

$$(4) \qquad P^T \equiv \left(P^P \cdot P^L\right)^{1/2} = \left(P(t)/P(t-1)\right)^T = \prod_{i=1}^{n} \left(p_i(t)/p_i(t-1)\right)^{\overline{s_i(t)}},$$

where

$$(5) \qquad \begin{aligned} P^P &\equiv \left(P(t)/P(t-1)\right)^P = \prod_{i=1}^{n} \left(p_i(t)/p_i(t-1)\right)^{s_i(t)} \\ P^L &\equiv \left(P(t)/P(t-1)\right)^L = \prod_{i=1}^{n} \left(p_i(t)/p_i(t-1)\right)^{s_i(t-1)} \end{aligned}$$

and

[12] See Appendix A.1 for a detailed derivation of the Divisia approach and the link to economic theory.

[13] Using the terminology of Diewert (1976), an index number formula is said to be *superlative* if it is *exact* (i.e., consistent with) for a flexible aggregator functional form (or a utility functional form). An aggregator functional form is said to be *flexible* if it can provide a second order approximation to an arbitrary twice differentiable linearly homogenous function.

[14] See ILO (2005, p. 323).

$$(6)\qquad \overline{s_i(t)} \equiv \frac{s_i(t)+s_i(t-1)}{2}$$
$$s_i(t) \equiv \frac{p_i(t)\cdot q_i(t)}{\sum_{i=1}^{n} p_i(t)\cdot q_i(t)}$$

is the arithmetic mean of the value shares of expenditure on product i between the two periods t and t–1, $s_i(t)$ and $s_i(t–1)$, where $p_i(t)$ and $q_i(t)$ are the price and quantity levels of product i in period t, respectively, $0 \leq s_i(h) \leq 1$ and $\sum_{i=1}^{n} s_i(h) = 1$ for $h = t$, t–1. We see that the Törnqvist price index uses information from both periods (i.e. prices *and* weights) symmetrically, by combining the geometric Paasche and Laspeyres price indices, to account for substitution between commodities caused by relative price level changes. The geometric Paasche and Laspeyres price indices, on the other hand, are asymmetrically weighted indices as value shares for the price relatives come from only one of the two periods considered, namely $s_i(t)$ or $s_i(t–1)$. Accordingly, the geometric Paasche and Laspeyres price indices can be interpreted as a measure of upper and lower bounds of substitution bias, see ILO (2005, p. 211).

Based on the definitions in (5), we may show that

$$(7)\qquad \ln\left(P^P/P^L\right) = \sum_{i=1}^{n} s_i(t-1)\left(\frac{s_i(t)}{s_i(t-1)}-1\right)\ln\left(\frac{p_i(t)/p_i(t-1)}{P^L}\right),$$

which is the (base period value share weighted) covariance between value share changes, $s_i(t)/s_i(t–1)$, and (logarithmic) relative price changes, $\ln[(p_i(t)/p_i(t–1))/P^L]$.[15] When relative price changes are positively (negatively) correlated with value share changes, the geometric Paasche price index will be larger (smaller) than the geometric Laspeyres price index. Thus, the choice of the two index number formulas in (5), like any other asymmetric weighted index, will normally matter for the final index number estimates in practice. Because the geometric Paasche and Laspeyres price indices can be regarded as equally valid approximations to the Divisia price index, but can differ considerably in empirical applications, we calculate relevant deflators of the GPFG by both P^P and P^L in addition to P^T to shed light on the substitution bias in our context.

Formally, the aggregate inflation rate measured by the current deflator, $\pi(t)$, is defined by

$$(8)\qquad \pi(t) \equiv \sum_{j=1}^{m} \alpha_j(t-1)\cdot\pi_j(t),$$

[15] See Balk (2008, p. 70).

where $\alpha_j(t-1)$ and $\pi_j(t)$ are the fixed income and equity weights for country j of the benchmark index in period $t-1$ and the corresponding country specific inflation rates measured in local currencies, respectively, the latter defined as $\pi_j(t) = \text{CPI}_j(t)/\text{CPI}_j(t-1)-1$, see NBIM (2012).[16] We see from (8) that the aggregate inflation rate is a weighted average of price relatives that is (for small price changes) consistent with the geometric Laspeyres price index as the underlying index number formula.

In this paper, we compare (8) with alternative deflators based on different weighting schemes, sets of international prices and aggregation methods. In so doing, we allow for the mismatch between the countries in the benchmark index and the countries subject to Norwegian imports. Thereby, exchange rate risk appears as discussed in Section 2.1. We calculate all measures of the deflator in a currency basket corresponding to the relevant import pattern.[17] The value of the investment portfolio measured in NOK is irrelevant from a national perspective, as it does not reflect the international purchasing power. However, as the GPFG is fully integrated with the state budget, and the expenses on the state budget are denominated in NOK, we also calculate all the measures of the deflator in NOK.

2.3 Price *levels* instead of price *relatives*

That superlative price indices provide good approximations to cost of living indices rests on specific assumptions about the consumer's preferences or the functional forms for the consumer's utility function. If the consumer has preferences that correspond to the translog cost function and engages in cost minimizing behaviour, the Törnqvist price index yields the true consumer's cost of living between two consecutive periods, see ILO (2005, p. 323). Another important assumption underlying superlative price indices being consistent with cost of living indices is that the consumer is free to choose between all goods and services. The China effect is in practice driven by the combination of large price level differences between countries and trade liberalisation, rather than changes in relative prices which is a central assumption underlying standard economic and index number theory. Accordingly, the Törnqvist price index applied to situations with barriers to trade will not represent the *true* cost of living index. To see this, consider a situation involving two countries, one low cost and one high cost country, the former having relatively high inflation of a particular tradable good. Then, assume that barriers to trade are reduced, leading to increased imports from the low cost country at the expense of imports from the high cost country. The increased availability of a low cost tradable good reduces the

[16] Whereas the current deflator is calculated by means of CPI's in *local* currencies, the weights in (8) are measured in a *common* currency as it is not possible to construct a weighting scheme in *local* currency: As the denominator in the weights is the sum of investments in all GPFG countries, the investments consequently must be measured in a *common currency*. The current deflator is based on *quarterly* data for CPI's, as made available to us by the Norwegian Ministry of Finance.

[17] The currency baskets are based on the corresponding bilateral exchange rates and weighting schemes and the geometric Laspeyres price index as the underlying aggregator formula, in line with the established practice of Norges Banks much used Norwegian import weighted exchange rate series dubbed I44, see http://www.norges-bank.no/Upload/Valutakurser/EN/forklaring_twi_eng.pdf.

price faced by consumers, and hence also the cost of living. However, applying the Törnqvist price index (like any other price index number formula) to this situation as a cost of living index, will make the measured cost of living increase. We may illustrate this problem by taking the natural logarithms of (4) with countries replacing commodities to obtain aggregate inflation, $\Delta \ln P(t)^T$, defined by

$$(9) \qquad \Delta \ln P(t)^T = \overline{s_1(t)} \Delta \ln p_1(t) + \left((1 - \overline{s_1(t)} \right) \Delta \ln p_2(t),$$

where $\overline{s_1(t)}$ is the average import share from the low cost country between period *t* and *t*−1 and $\Delta \ln p_1(t)$ and $\Delta \ln p_2(t)$ are the inflation rates in the low and high cost country in period *t*, respectively. Now, increased imports from the low cost country increase the weighting of inflation in the low cost country and reduce the weighting of inflation in the high cost country. Because inflation is relatively high in the low cost country, aggregate inflation increases and the Törnqvist price index does not represent the *true* cost of living, which has decreased in this situation. This problem 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.

The empirical literature on the China effect seeks to include the deflationary effect of the observed switching of imports towards low cost countries by employing either a geometric or an arithmetic mean of price *levels* from different countries, see e.g. Pain *et al.* (2006) who study the impact of imports from emerging countries on inflation in OECD countries, Nickell (2005), Wheeler (2008) and Coille (2008) who analyse the evolution of inflation in the United Kingdom, Thomas and Marquez (2009) who study measures of foreign prices when modelling US import prices, Kamin *et al.* (2006) who analyse the impact of Chinese exports on global import prices, Røstøen (2004) who identifies foreign price impulses to imported consumer goods in Norway and Benedictow and Boug (2013) who empirically use a similar framework to calculate foreign price impulses to imported textile and wearing apparels in Norway. The geometric mean of price *levels* is defined by

$$(10) \qquad P(t) = \prod_{i=1}^{n} p_i(t)^{s_i(t)}.$$

To see how the geometric mean of price *levels* can be used to identify the impact of gradual removal of trade barriers on aggregate inflation, we take the natural logarithms of (10), continue to assume one low cost and one high cost country for simplicity (without loss of generality) and apply the quadratic approximation lemma, see Diewert (1976), to get[18]

$$(11) \qquad \Delta \ln P(t) = \overline{s_1(t)}\Delta \ln p_1(t) + \left(1-\overline{s_1(t)}\right)\Delta \ln p_2(t) + \Delta s_1(t)\left(\overline{\ln p_1(t)} - \overline{\ln p_2(t)}\right),$$

where $\overline{\ln p_1(t)}$ and $\overline{\ln p_2(t)}$ are the average price *levels* of period t and t–1 of the low cost and the high cost country, respectively. Comparing (9) and (11), we see that aggregate inflation based on the Törnqvist price index is adjusted by the term $\Delta s_1(t)\left(\overline{\ln p_1(t)} - \overline{\ln p_2(t)}\right)$, which is negative if imports from the low cost country increase due to lowering of trade barriers, that is the China effect. The larger the change in the import share and the larger the difference in price levels, the larger is the deflationary impulse in $\Delta \ln P(t)$. We notice that the China effect is zero only in the special cases when the import shares are constant $(\Delta s_1(t) = 0)$ and/or when the composition of trade changes between countries with identical price levels $\left(\overline{\ln p_1(t)} - \overline{\ln p_2(t)} = 0\right)$. Hence, (11) is consistent with integration of low cost countries in the world trade, putting downward pressure on aggregate inflation. In Appendix A.3, we show that the China effect can be decomposed as

$$(12) \qquad \Delta s_1(t)\left(\overline{\ln p_1(t)} - \overline{\ln p_2(t)}\right) = \Delta s_1(t)\left(\ln\left(p_1(0)/p_2(0)\right) + \overline{\Delta \ln p_1(t,0)} - \overline{\Delta \ln p_2(t,0)}\right),$$

where $\ln\left(p_1(0)/p_2(0)\right)$ is the logarithm of the relative price level between the low cost and the high cost country in the starting period, i.e., period zero, and $\overline{\Delta \ln p_1(t,0)}$ and $\overline{\Delta \ln p_2(t,0)}$ are the average inflation rates in period t relative to period zero in the low cost and the high cost country, respectively. Accordingly, higher inflation in the low cost country will over time dampen the initial China effect and vice versa. Although a geometric mean (like any other mean) of price *levels* deviates from classical index number theory, we also calculate alternative deflators of the GPFG based on (11) to shed light on the magnitude of the China effect in our aggregation problem.

3. Data

Our calculations of the alternative measures of the deflator, and thereby of estimates of the real return, are mainly based on yearly data running from 1998 to 2012. Because some of the data used in the calculations of the deflators are available on an annual basis only, we calculate nominal return and inflation as the percentage change in the annual average from year t–1 to year t. This may have significant impact on the measures of nominal return, inflation and real return for individual years, but

[18] See Appendix A.2 for a detailed derivation of (11).

also for the sample period averages when the sample period is short. According to the Global Investment Performance Standard (henceforth GIPS), annual nominal return should be measured as the percentage change in the value of the GPFG from the beginning of the year (December 31 year $t-1$) to the end of the year (December 31 year t), see NBIM (2012). As a comparison, we also calculate nominal return and alternative measures of the deflator by means of GIPS when monthly data on international prices and weighting schemes are available. Whereas the various international prices and exchange rates are gathered from different databases available in Macrobond, foreign trade statistics and country specific investment weights of the benchmark index for equities and fixed income of the GPFG are gathered from Statistics Norway and Norges Bank, respectively. Data for nominal return of the GPFG and the corresponding currency basket (henceforth I36), starting in 1998, were made available to us from the Norwegian Ministry of Finance. In what follows, we present in more detail the data used for international prices, weighting schemes and relative price levels between countries, and outline the construction of the import deflator from the Norwegian national accounts with particular attention to the China effect.

3.1 Price measures

We apply three alternative price measures as proxies for prices faced by Norwegian importers, namely GDP deflators, CPI's and export prices of Norway's trading partners. The GDP deflator is the broadest measure for the overall price developments of an economy. Thereby, it contains several categories of goods and services of minor relevance for Norwegian importers, as for instance domestic investments and government expenditures. The CPI is a narrower price measure than the GDP deflator and is designed to reflect the price developments of goods and services consumed domestically. That said, the CPI also contains country specific trade margins, excise taxes and value added taxes not very relevant for Norwegian importers. Moreover, the discrepancy between the composition of goods and services in the CPI and the composition of exported goods and services from a country will in general also be significant. Aggregate export prices are the closest proxy available for the prices faced by Norwegian importers. However, we must keep in mind that aggregate export prices reflect prices on aggregate exports *from* each of Norway's trading partners, and not the (desirable) prices on specific goods and services exported from each trading partner *to* Norway. Comparable data for the latter is not available. Aggregate export prices of a particular country are generally not the same as prices of imports into Norway because the composition of Norwegian imports from a given country is not the same as the aggregate composition of exports from that country. Even for identical goods, exports from a given country are often sold at different prices in different countries. The available data for consumer prices, export prices and GDP deflators are all price indices (with a base year value of unity) measured in local currencies. We use bilateral exchange rates to convert these price indices into a common currency and divide the price indices (measured in a common currency) period by period over the entire sample period to obtain price level relatives ready for numerical calculations of the alternative deflators. These price relatives are then chained in order to obtain a time series of a multiple of the bilateral indices in (4) and (5), see Appendix A.4.

3.2 Countries

The benchmark index for equities and fixed income has been gradually expanded during the sample period to include 36 currencies, listed in Appendix A.5. Which countries to include in the alternative weighting schemes based on different measures for imports are not clear cut. We have settled for including all countries constituting more than one per cent of Norwegian total imports of goods[19] and of total world gross product in 2011 when calculating import weights and GDP weights, including 20 and 18 countries, respectively. Together the 20 countries constituted around 85 per cent of total Norwegian imports of goods in 2011, while the 18 countries constituted close to 80 per cent of total world gross product. The future composition of imports to Norway depends on many factors, including developments in the international division of labour. An increasing proportion of imports is likely to come from emerging economies or low-cost countries with high economic growth, one important example being China. During the last 15 years or so China has increased its share of total imports to Norway from about 2 per cent to 11 per cent, which is also reflected in the strong growth in China's share of total world gross product. The countries included in the weighting schemes based on import weights and GDP weights are also listed in Appendix A.5. As opposed to the practice of the current deflator, we treat countries within the euro area as separate countries in the weighting schemes based on import weights and GDP weights. Hence, we are able to accommodate substitution effects among countries within the euro area caused by relative price changes in the alternative deflators of the GPFG. Also, we notice that China as one important low cost, high inflation country is not included in the weighting scheme for the current deflator, as opposed to the weighting schemes based on import weights and GDP weights.

3.3 Relative price levels

We recall from (12) that figures of relative price levels between countries in the starting period, $p_1(0)/p_2(0)$, are needed in order to calculate the China effect. As discussed in Benedictow and Boug (2013), we may utilise data for purchasing power parities between countries and construct relative price levels in the starting period by means of the formula

[19] Data for Norway's imports of services from individual countries are not available.

(13) $$p_1(0)/p_2(0) = \frac{GDP_1^{NOM}(0)/GDP_1^{PPP}(0)}{GDP_2^{NOM}(0)/GDP_2^{PPP}(0)},$$

where $GDP_1^{NOM}(0)$ and $GDP_1^{PPP}(0)$ are nominal GDP and purchasing power parity adjusted volume of GDP for country 1 in the starting period, respectively, and $GDP_2^{NOM}(0)$ and $GDP_2^{PPP}(0)$ are the corresponding figures for country 2, that is the numeraire country. Although the bilateral distribution of the China effect is sensitive to the choice of numeraire country, the size of the *aggregate* China effect is not when more than two countries are involved in the calculations based on (12). Relative price levels calculated from (13) are unitless and easy to interpret for our purposes. For instance, $p_1(0)/p_2(0)$ equal to 0.5 would imply that the overall price level in country 1 is 50 per cent of that in country 2 in the starting period. Table 1 shows calculated relative price levels in 1998, which is the starting period of our sample period, based on (13) and USA as the numeraire country.

Table 1. Relative price levels. 1998

DK	CH	JP	SE	FI	DE	FR	GB	BE	NL
1.33	1.31	1.30	1.26	1.17	1.14	1.13	1.11	1.07	1.05
US	IT	ES	CA	BR	KR	PL	CZ	CH	RU
1.00	0.93	0.83	0.82	0.76	0.55	0.50	0.44	0.32	0.30

Notes: DK (Denmark), CH (Switzerland), JP (Japan), SE (Sweden), FI (Finland), DE (Germany), FR (France), GB (Great Britain), BE (Belgium), NL (Netherlands), US (United States), IT (Italy), ES (Spain), CA (Canada), BR (Brazil), KR (South Korea), PL (Poland), CZ (Czech Republic), CH (China) and RU (Russia) are land codes used in the Foreign Trade Statistics of Statistics Norway. Source: Penn World Table, Macrobond.

Our calculations indicate that the overall price levels in Russia and China were around 30 per cent of that in the United States in 1998. The corresponding figures for Denmark, Switzerland, Japan and Sweden are around 130 per cent. We recognise that the figures in Table 1 are good proxies only to the extent that relative price levels on tradable goods are similar to the purchasing power parity adjusted GDP relative price levels, an assumption that needs not hold in practise. For instance, due to the relatively high presence of comparative advantages in the production of tradable goods, we could expect price level differences between high and low cost countries to be even higher. If this is the case, the China effect will be underestimated and the aggregate inflation calculated by means of (11) will be overestimated. However, it could also be that exporters of goods and services from low cost countries set their prices somewhat below the competitors' prices and still gain market shares. Consequently, the price level of imports from low cost countries may be higher than that calculated from the purchasing power parity adjusted GDP price levels. In this case, the China effect will be overestimated and the aggregate inflation will be underestimated. We use the relative price levels in Table 1 as the best educated guesses to calculate the likely magnitude of the China effect in our case.

3.4 The import deflator

Our analysis, as noted in the introduction, also includes the import deflator from the Norwegian national accounts. The computation of the import deflator is rather complex and may be briefly described as follows.[20] First, for each comparable group of goods or services the sum of import value (at the Norwegian border) from all origin countries is divided by the corresponding sum of import volume in each period in order to derive a time series of unit prices. Then, price relatives defined as the unit price in each period divided by the unit price in the base period for each comparable group of goods or services are aggregated by means of the Paasche price index to obtain the overall import deflator of goods and services. The China effect is in principle captured in the import deflator through the use of unit prices of homogenous products across countries. However, when comparability of quality of products across countries is dubious, the relevant good or service will be taken out of the computation, and replaced by imputed price relatives. Hence, the import deflator may in practice underestimate the China effect and overestimate inflation to the extent that quality differences are not properly accounted for.[21] We convert the import deflator, which is originally measured in NOK, to a (closely) corresponding currency basket by the import weighted exchange rate series, I44, including the 44 countries covering 97 per cent of Norwegian imports in 2012. We now turn to numerical measures of the deflator of the GPFG, and refer to Appendix A.5 for details about data definitions, sources and availability.

4. Numerical measures of the deflator

In this section, we present numerical measures of the deflator of the GPFG based on yearly data, (4), (5), (8) and (11) as the underlying aggregator formulas and the different sets of international prices

[20] Unfortunately, there is no comprehensive documentation of the import deflator available, see http://www.ssb.no/en/uhvp/ for an outline. Our brief description of the computation of the import deflator is based on interviews with specialists at Statistics Norway.

[21] To illustrate this, we consider an example involving two countries, one low cost and one high cost country with exports quantities x_1 and x_2 of a particular consumer good and corresponding price levels p_1 and p_2, respectively. We assume $p_1 < p_2$. The average unit price for homogenous products $\overline{P} = \frac{x_1 p_1 + x_2 p_2}{x_1 + x_2} = \left(\frac{x_1}{x_1 + x_2}\right) p_1 + \left(\frac{x_2}{x_1 + x_2}\right) p_2 = \beta p_1 + (1-\beta) p_2$.

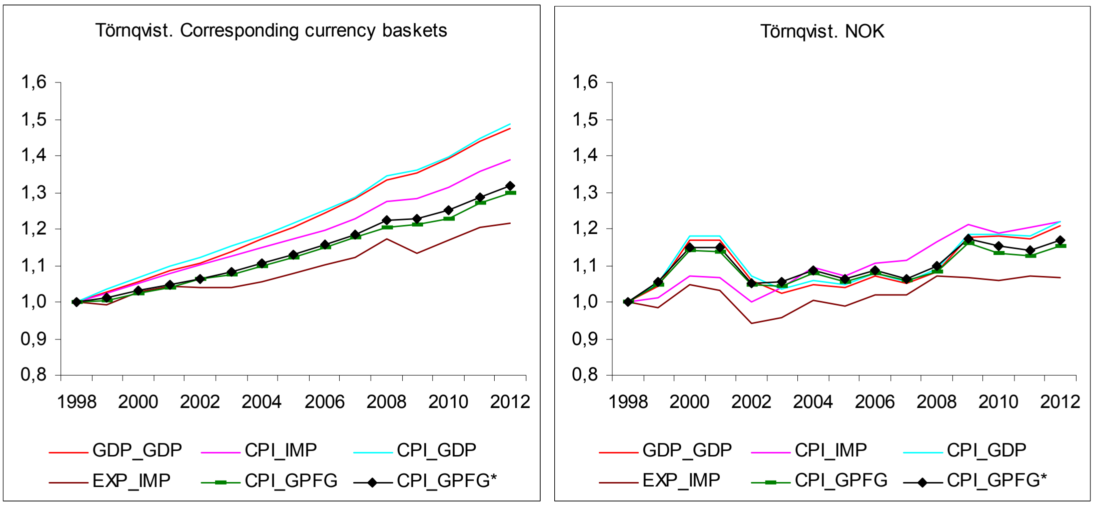
Now, let $x_2 = \kappa \tilde{x}_2$, where κ<1 represents product quality differences across the two countries, such that the average unit price $\tilde{P} = \frac{x_1 p_1 + \kappa \tilde{x}_2 p_2}{x_1 + \kappa \tilde{x}_2} = \left(\frac{x_1}{x_1 + \kappa \tilde{x}_2}\right) p_1 + \left(\frac{\kappa \tilde{x}_2}{x_1 + \kappa \tilde{x}_2}\right) p_2 = \tilde{\beta} p_1 + (1-\tilde{\beta}) p_2$. It follows that $\tilde{\beta} > \beta$ and $\overline{P} > \tilde{P}$ for given prices p_1 and p_2. If the products from the two countries are considered heterogeneous (that is κ sufficiently large) they are left out of the computation of the average unit price at the expense of the China effect, which thus will be underestimated in the overall import deflator. Leaving out products from the computation of the average unit price may occur relatively often when a switch from high cost to low cost countries prevails. An important example may be the significant increase in relatively low quality imports of clothing from China over the last two decades. See e.g. Silver (2010), for a thorough discussion of pitfalls of using unit value indices with customs data.

and weighting schemes described above.[22] First, we present Törnqvist price index based measures of the deflator using (4) together with the current deflator calculated by (8) and discuss implications of measuring the deflator in corresponding currency baskets and in NOK. Second, we pay particular attention to the alternative sets of international prices involved in the calculations and their impact on the measures of the deflator. Third, we discuss consequences for the measures of the deflator of different weighting schemes and to which extent these schemes include countries with a low level of cost and/or a high rate of inflation. Fourth, we compare the Törnqvist price index based measures of the deflator with the geometric Paasche and Laspeyres price index based measures using (5) to shed light on the upper and lower levels of substitution bias. Finally, we present the import deflator from the Norwegian national accounts together with alternative measures of the deflator using (11) to calculate the magnitude of the China effect in addition to the Törnqvist based inflationary effects in our empirical context.

4.1 Current and alternative deflators

As outlined in the introduction, we present measures of the deflator based on CPI's and GPFG weights (labelled CPI_GPFG), CPI's and import weights (CPI_IMP), CPI's and GDP weights (CPI_GDP), GDP deflators and GDP weights (GDP_GDP) and export prices and import weights (EXP_IMP). Figure 1 shows the alternative measures of the deflator calculated by means of the Törnqvist price index together with the current deflator based on CPI's and GPFG weights and (8) as the underlying aggregator formula (CPI_GPFG*), all of which are measured in corresponding currency baskets (Panel a) and in NOK (Panel b).

Figure 1. Measures of the deflator (1998=1)



Panel a **Panel b**

[22] See Appendix A.6 for consequences for the calculated deflator of restricting the countries involved in the weighting scheme to the four major OECD economies of USA, euro area, Japan and Great Britain.

We observe considerable differences in the development of the alternative measures. The deflator based on consumer prices and GDP weights provides the highest inflation throughout the sample period when measured in the corresponding currency basket, whereas the deflator based on export prices and import weights delivers the lowest inflation. The deflators based on CPI's and GPFG weights are somewhere in between the highest and lowest inflationary measures, irrespective of being measured in the corresponding currency basket or in NOK.[23] The developments of inflation as well as the ranking of the measures of the deflator are highly dependent on the currency of measurement. Measured in NOK inflation is substantially lower in all cases because of the marked appreciation of the Norwegian currency since the early 2000s. We notice, though, that measured inflation in terms of NOK is relatively high in the first years of the sample period, reflecting the depreciation of the NOK in the same period. The ranking of the deflators is even turned upside down in some years when switching from corresponding currency baskets to NOK. Interestingly, the deflator based on export prices and import weights stands out as an exception, displaying by far the lowest inflation among all the alternative measures, irrespective of the currency of measurement.

Table 2 shows average annual inflation rates over the sample period, calculated from the different measures of the deflator and measured in the corresponding currency baskets and in NOK. Measured in corresponding currency baskets, the range of average annual inflation rates goes from 1.4 to 2.9 per cent. The deflators, based on CPI's and GPFG weights, deliver average annual inflation rates just below 2.0 per cent. The estimates in NOK paint the same picture, although inflation rates are considerably lower due to the appreciation of the NOK.

Table 2. Measures of the deflator. Average annual inflation rates.[1] 1998 - 2012. Per cent. Corresponding currency basket (NOK in parenthesis).

CPI_GDP[2]	GDP_GDP[2]	CPI_IMP[2]	CPI_GPFG[2]	CPI_GPFG*[3]	EXP_IMP[2]
2.9	2.8	2.4	1.9	1.99	1.4
(1.4)	(1.4)	(1.4)	(1.0)	(1.13)	(0.5)

Notes: [1] Geometric mean of annual percentage change from the previous year. [2] CPI_GDP, GDP_GDP, CPI_IMP, CPI_GPFG and EXP_IMP denote the deflators based on CPI's and GDP weights, GDP deflators and GDP weights, CPI's and import weights, CPI's and GPFG weights and export prices and import weights, respectively, and the Törnqvist price index as the aggregator formula, equation (4). [3] CPI_GPFG* denotes the current deflator based on CPI's in local currencies and GPFG weights and equation (8) as the aggregator formula.

The current practice of calculating the deflator by weighting together inflation rates measured in *local currencies* leads to an inconsistency because it is not possible to derive corresponding weights, as previously noted: As the denominator in the weights is the sum of investments in each of the GPFG countries, the investments consequently must be measured in a *common currency*. Measuring the

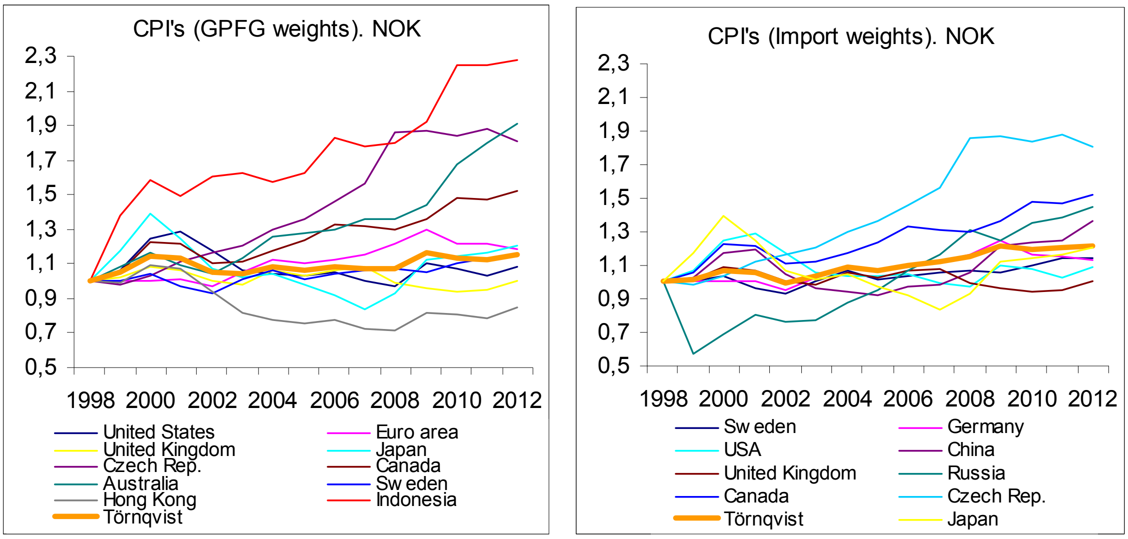
[23] Measuring the deflator in other *national* currencies than NOK, (e.g. USD) would not affect the ranking of the deflators, as that would just imply dividing all the measures by the same number (i.e. the NOK/USD exchange rate).

underlying inflation rates in a common currency rather than in local currencies reduces the estimate of average annual inflation in the case of the current deflator (CPI_GPFG*) from 1.99 (1.13) per cent to 1.97 (1.11) per cent.

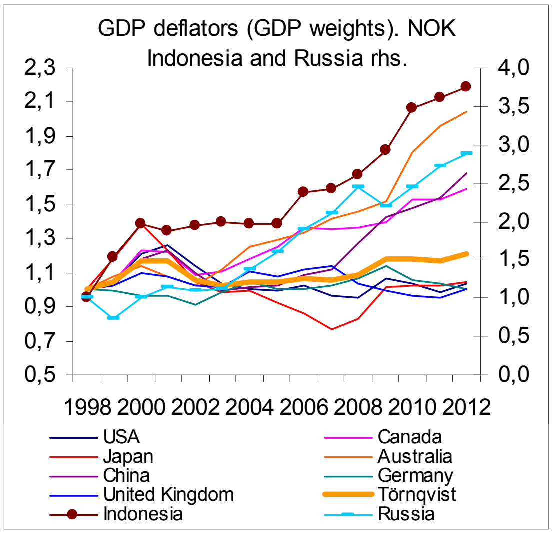
4.2 International prices

We now discuss in more detail causes to differences in the measures of the deflator stemming from the underlying proxies for international prices. Figure 2 shows the main consumer prices underlying the deflators based on GPFG weights (Panel a), the main consumer prices underlying the deflator based on import weights (Panel b), the main GDP deflators underlying the deflator based on GDP weights (Panel c) and the main export prices underlying the deflator based on import weights (Panel d), all of which are measured in NOK and compared with the corresponding Törnqvist price index. Panel c is also closely applicable with respect to countries and corresponding consumer prices underlying the deflator based on GDP weights.

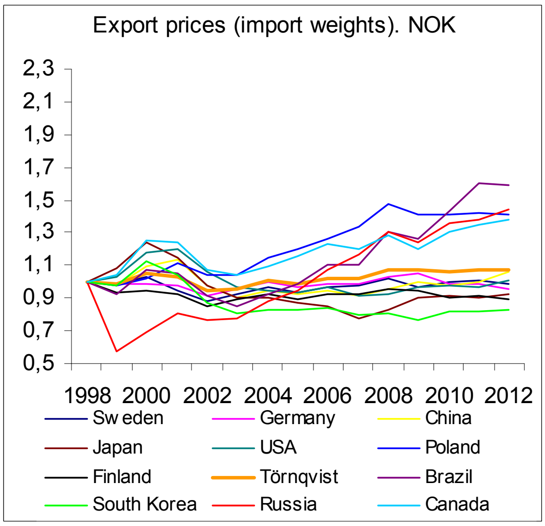
Figure 2. Alternative international prices measured in NOK (1998=1)



Panel a **Panel b**



Panel c



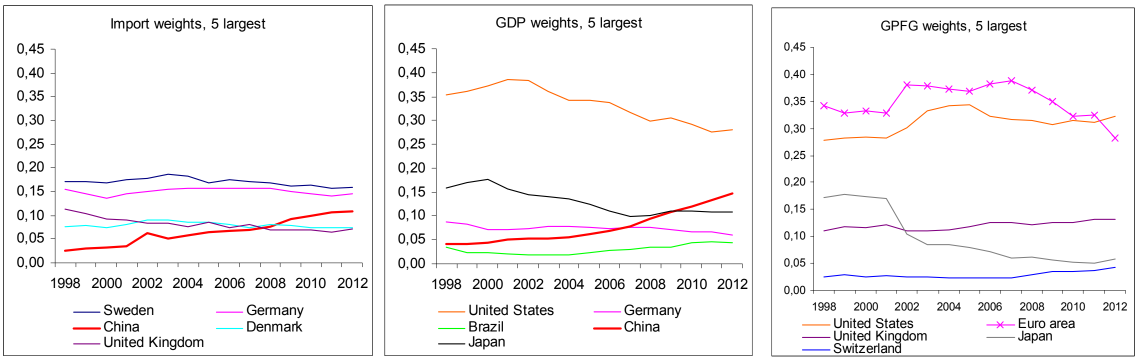
Panel d

First, we observe that Indonesia, Australia, the Czech Republic and Canada, with a joint weight of around 5 per cent in 2012, represent the main high inflation countries among the GPFG countries. Similarly, Hong Kong and United Kingdom, which together constitute about 15 per cent of the aggregate, stand out as the main low inflation countries. For the euro area, the United States, Japan and Sweden, with a joint weight of nearly 70 per cent, the relatively slow growth of the consumer prices matches rather closely that of the Törnqvist price index. Turning to the deflator based on CPI's and import weights, we see that Russia and China, with a joint weight of around 11 per cent of the aggregate in 2012, represent additional high inflation countries. The striking Russian deflation in 1999 is due to the strong depreciation of the ruble against NOK. We observe that Russia and China, which together constitute around 15 per cent of the deflator based on GDP weights, also stand out as additional high inflation countries when measured by GDP deflators. That the deflator based on export prices and import weights exhibits lowest inflation during the sample period can mainly be explained by export prices having increased relatively slow, possibly due to strong international competition. For 7 out of the 18 largest exporters to Norway, export prices were lower in 2012 than in 1998. The clearest exceptions are Poland, Russia, Brazil and Canada where export prices increased by 40 to 60 per cent during the same period. With a joint weight of around 10 per cent in 2012, these countries thus contribute somewhat to inflationary impulses in the deflator based on export prices and import weights.

4.3 Weighting schemes

The choice of weighting schemes matters for the weights assigned to each country and the changes in relative weights between countries over time, thereby also for the measures of the deflator. As previously mentioned, reduced trade barriers and increased globalisation have led to significant changes in trade patterns over the last two decades. The share of Norwegian imports coming from low cost countries has increased at the expense of high cost countries, European countries in particular. Also, more developed capital markets have increased the investment possibilities for the GPFG in the same period, introducing new countries as well as asset classes in the portfolio. There are, however, considerable differences between the countries subject to Norwegian imports and those subject to Norwegian capital investments. Figure 3 depicts import weights (Panel a), GDP weights (Panel b) and GPFG weights (Panel c) for the five largest countries used in the calculations of the different measures of the deflator.

Figure 3. Alternative weighting schemes (per cent)



Panel a **Panel b** **Panel c**

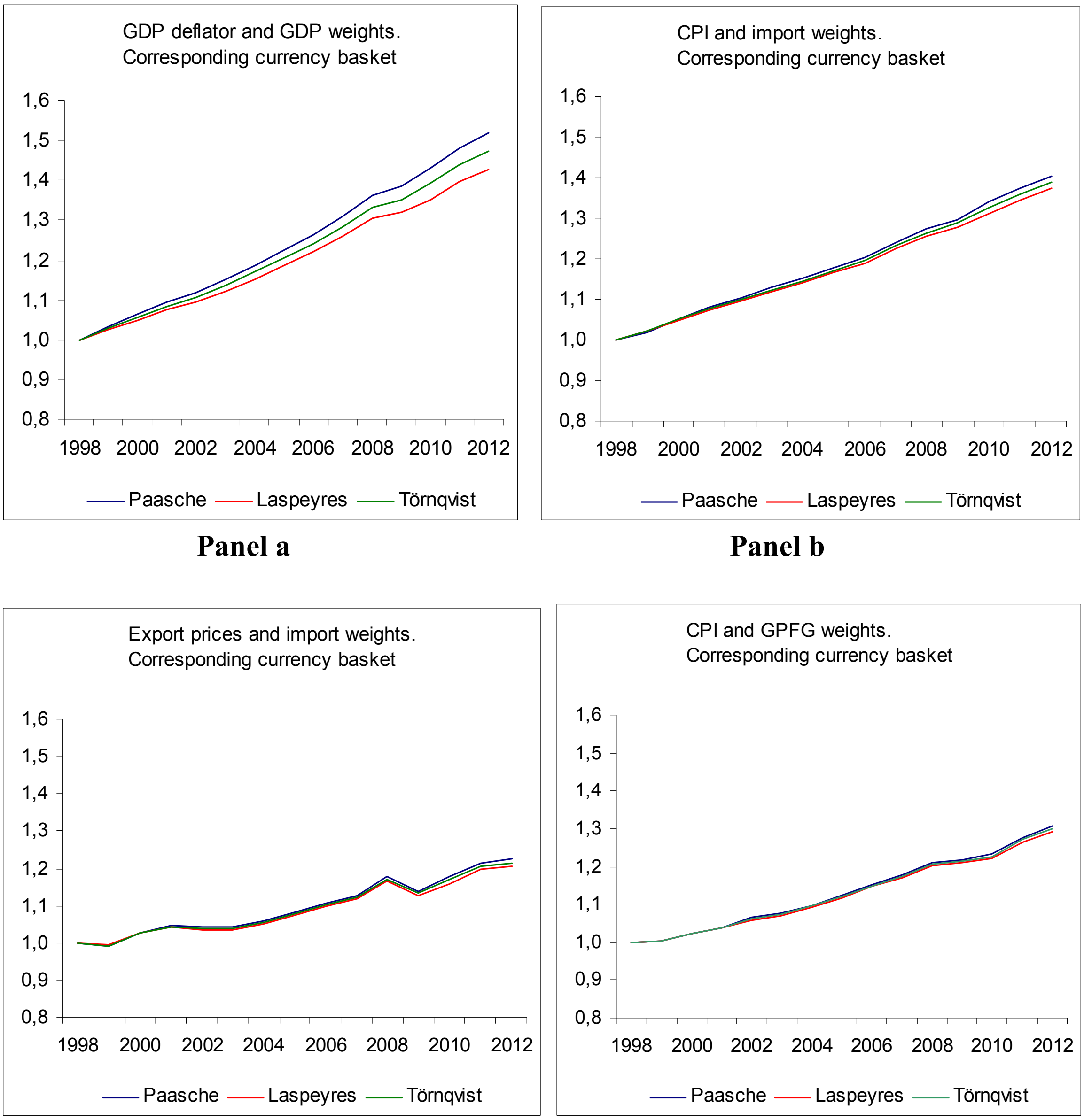
The low cost and high inflation country China's emergence in global trade is remarkable. China is now after Sweden and Germany the third most important origin of Norwegian imports. As a share of world GDP, China's economy is now second only to the US economy. Whereas China constitutes more than 10 per cent of Norway's imports as well as of the world economy, the GPFG investments in China are absent throughout the sample period. [24] Accordingly, the fact that countries with low consumer price inflation dominate and that high inflation countries like Russia and China have weights close to or equal to zero in the GFPG weighting scheme mainly explains the relatively low inflation measured by the current deflator. A common feature, though, of the GDP and GPFG weighting schemes is the significant decrease in the high cost and low inflation country Japan's shares of global GDP and of GPFG investments during the sample period, which increases inflationary impulses somewhat using these weighting schemes. Another, probably minor, feature of the GPFG weighting scheme is that it includes the euro area aggregate, and would thus fail to capture any effects from Norwegian imports switching between high and low cost/inflation countries within the euro area.

[24] Chinese stocks included in the benchmark index are listed in Hong Kong. The total investment share in Hong Kong has increased gradually in recent years, to 1.4 per cent in 2011.

4.4 Methods of aggregation

The choice of index number formula may also have substantial impact on the alternative measures of the deflator. Figure 4 shows four of the measures of the deflator calculated by means of both the geometric Paasche and Laspeyres price indices in addition to the Törnqvist price index as the underlying aggregator formula, all of which are measured in the corresponding currency basket.

Figure 4. Alternative index number formulas (1998=1)



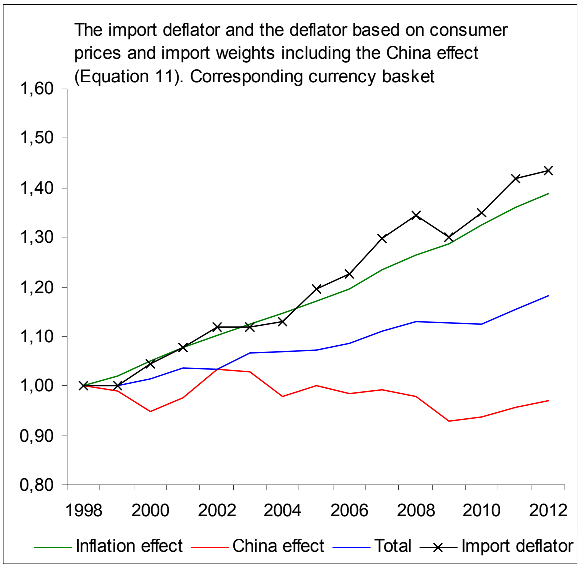
Panel c **Panel d**

We see that the geometric Laspeyres price index provides the lower boundary in all measures of the deflator whereas the geometric Paasche price index provides the upper boundary, implying a positive correlation between relative price changes and value share changes, cf. equation (7) in Section 2.2. In the case of GDP deflators and GDP weights, the geometric Paasche price index is as much as 9 percentage points (corresponding to about 20 *per cent*) higher than the geometric Laspeyres price index after 14 years (Panel a). The deflator based on CPI's and GDP weights provides similar results. Major contributions to the substantial difference stem from the (highly correlated) high inflation and rapidly increasing GDP shares of China as well as falling prices and decreasing GDP weights of Japan. Applying consumer prices and import weights, the difference between the two index number formulas is considerably smaller at 3.2 percentage points (9 *per cent*) (Panel b). The smaller difference is mainly attributed to negative correlation between (increasing) prices and falling import weights for several OECD countries, notably Sweden, counteracting the corresponding positive correlation of China in particular. In the cases of export prices and import weights (Panel c) and consumer prices and GPFG weights (Panel d), the differences between the geometric Paasche and Laspeyres price indices accumulate to 1.9 and 1.6 percentage points (9 and 5 *per cent*), respectively, at the end of the sample period. Hence, we conclude that the substitution bias may be substantial, making the choice of index number formula important for inflation estimates.

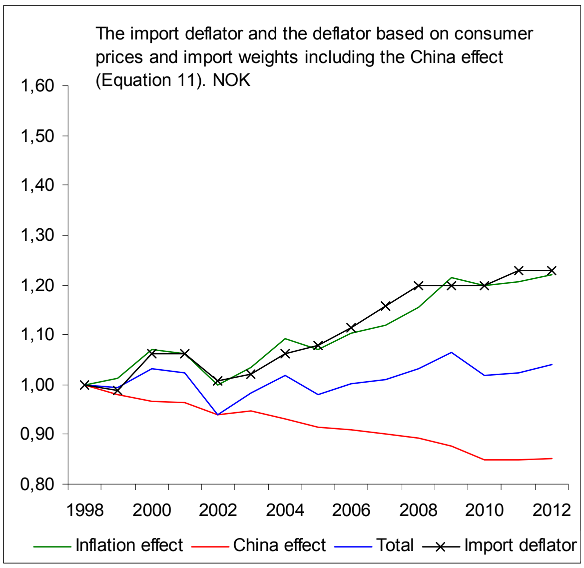
4.5 Magnitude of the China effect

We recall from Section 2.3 that the Törnqvist price index based measures of the deflator may overestimate aggregate inflation to the extent that trade barriers are present and low cost countries are included in the weighting schemes. Figure 5 displays the import deflator from the Norwegian national accounts together with measures of the deflator based on consumer prices and import weights (Panel a and Panel b) and export prices and import weights (Panel c and Panel d), calculated by means of (11) to capture both the China effect and the Törnqvist price index based inflationary effects discussed above.

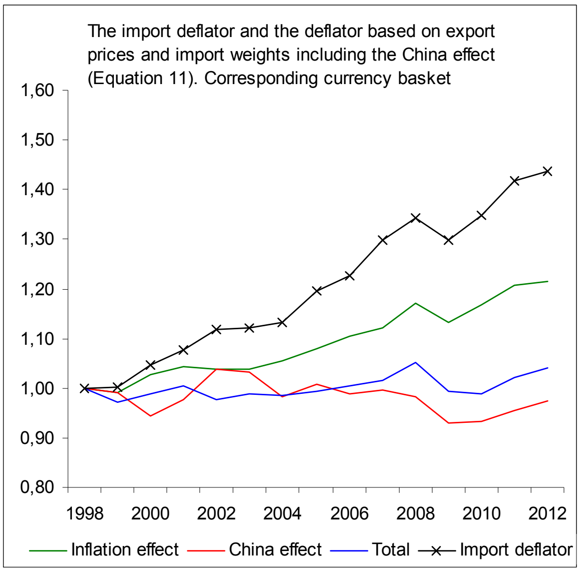
Figure 5. Measures of the deflator including the China effect (1998=1)



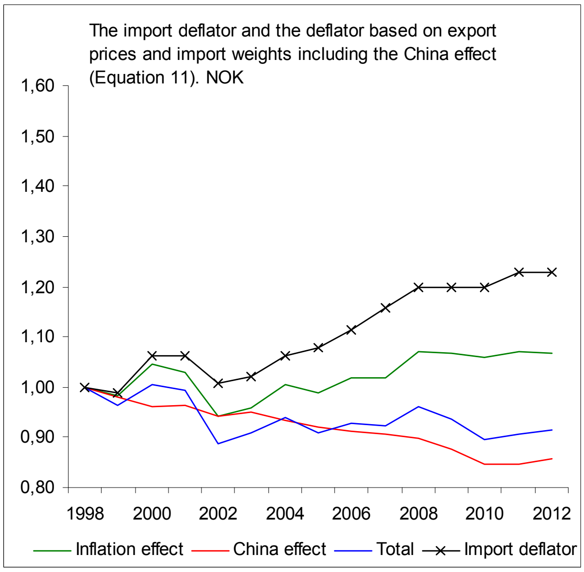
Panel a



Panel b



Panel c



Panel d

We observe that the magnitude of the calculated China effect is substantial, irrespective of being measured in corresponding currency baskets or in NOK. Also, we notice that the choice between consumer prices and export prices does not matter much for neither the magnitude nor the development of the China effect. In terms of the decomposition formula in (12), this implies that overall, the initial relative price levels between countries, and not differences in inflation rates over time, largely have driven the China effect. Our calculations show that the shift in imports from high cost to low cost countries has pushed aggregate inflation down to moderate levels throughout the sample period, and even to *deflation*, as measured by the deflator based on export prices and import weights (measured in NOK). Applying (12) for each single country reveals, not surprisingly, that China with an overall price level of only 30 per cent of that in the United States in 1998 (cf. Table 1), combined with an import share increasing by close to 10 percentage points, explains on average nearly 60 per cent of the aggregate China effect during the sample period. The corresponding figures for Poland, Russia and the Czech Republic, the other main low cost countries in our study, are approximately 8, 7 and 4 per cent, respectively. Interestingly, the import deflator from the Norwegian national accounts delivers relatively high inflation throughout the sample period, especially compared to the measure based on export prices and import weights including the China effect. Although the import deflator in principle captures the China effect through the use of unit prices of homogenous products across countries, it may in practice underestimate the China effect and overestimate inflation to the extent that quality differences are not properly accounted for when imports switch from high cost to low cost countries.

Table 3 shows average annual inflation rates over the sample period based on the deflators with and without the China effect included for comparison, measured in both corresponding currency baskets and in NOK. As discussed in Section 4.1, replacing consumer prices by export prices reduces measured average annual inflation by close to one percentage point when only Törnqvist price index based inflationary impulses are calculated. Accounting also for the China effect reduces measured average annual inflation by one additional percentage point, stretching out the range between the lowest and highest estimates of average annual inflation to more than 2 percentage points. Using a similar framework, Nickell (2005) finds that switching to low cost countries has since 2000 reduced the inflationary impulses to the United Kingdom by close to 0.6 percentage points annually.[25] According to Benedictow and Boug (2013), the shift in Norwegian imports of clothing from high to low cost countries has on average pushed down international price impulses (measured in foreign currency) by as much as 2 percentage points each year since the early 1990s. Røstøen (2004), who uses an arithmetic mean instead of a geometric mean of price levels, finds the average annual China effect to be even larger when it comes to international price impulses on Norwegian imports of clothing, estimated at around 3 percentage points over the period from 1991 to 2004. Noticeably, we calculate average annual *deflation* of 0.6 per cent in the case of the deflator based on export prices and import weights, measured in NOK, compared to average annual *inflation* of 1.5 per cent in the case of the import deflator from the Norwegian national accounts. We conclude from the findings in this section that the China effect is likely to be of major importance, assuming that purchasing power parity adjusted GDP relative price levels are reasonable proxies to relative price levels on tradable goods.

Table 3. Measures of the deflator. Average annual inflation rates.[1] 1998 - 2012. Per cent. Corresponding currency basket (NOK in parenthesis).

	Without the China effect[3]		With the China effect[4]	
Import deflator[2]	CPI_IMP	EXP_IMP	CPI_IMP_CH	EXP_IMP_CH
2.6	2.4	1.4	1.2	0.3
(1.5)	(1.4)	(0.5)	(0.3)	(–0.6)

Notes: [1] Geometric mean of annual percentage change from the previous year. [2] The import deflator from the Norwegian national accounts, based on unit prices and the Paasche price index as the aggregator formula. [3] Equation (4) is used as the aggregator formula. CPI_IMP and EXP_IMP denote the deflators based on CPI's and import weights and export prices and import weights, respectively. [4] Equation (11) is used as the aggregator formula. CPI_IMP_CH and EXP_IMP_CH denote the deflators based on CPI's and import weights and export prices and import weights, respectively, both including the China effect.

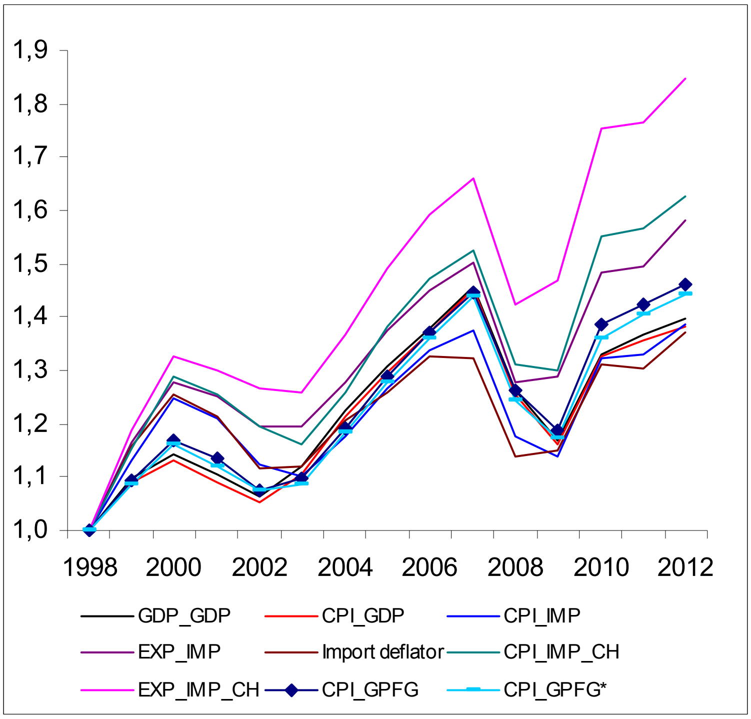
5. Estimates of real return

Having established different measures of the deflator, we now turn to calculations of the corresponding estimates of the *real* return of the GPFG based on (2) in Section 2.1 and given figures

[25] Referring to his equation (1) and using our notation, Nickell (2005) applies $\Delta \ln P(t) = s_1(t)\Delta \ln p_1(t) + (1 - s_1(t))\Delta \ln p_2(t) + \Delta s_1(t)(\ln p_1(t) - \ln p_2(t))$ as the underlying aggregator formula. We notice that the inflationary terms in this equation are identical to those from a geometric Paasche price index and that the China effect is somewhat different from that in our equation (11).

of nominal return. We have seen that currency of measurement is of major importance for the development of the different measures of the deflator. This is not, however, the case for estimates of real return as differences in measured inflation stemming from the currency of measurement are mirrored in the related measures of nominal return. It follows that estimates of real return are more or less independent of the currency of measurement. Figure 6 shows the development in the estimates of real return over the sample period based on the alternative measures of the deflator in Section 4, that is the Törnqvist price index based measures based on CPI's and GPFG weights (CPI_GPFG), CPI's and import weights (CPI_IMP), CPI's and GDP weights (CPI_GDP), GDP deflators and GDP weights (GDP_GDP) and export prices and import weights (EXP_IMP), the current deflator based on CPI's and GPFG weights and (8) as the aggregator formula (CPI_GPFG*), the import deflator from the Norwegian national accounts (Import deflator) and the deflators including the China effect based on CPI's and import weights (CPI_IMP_CH) and export prices and import weights (EXP_IMP_CH).

Figure 6. Estimates of real return based on alternative deflators (1998=1)



We notice that the real return of the GPFG has been very volatile during the sample period. Most notably, real return increased substantially during the years between 2003 and 2007 of international economic upturn and likewise dropped dramatically following the financial crisis. By 2012, the real return has more or less recovered to the level before the financial crisis settled in by most measures. The recovery was achieved somewhat earlier for the measures including the China effect, while the two measures based on GDP weights still had some way to go before reaching the peak of 2007. The relatively quick recovery by the former measures stems partly from the fact that they capture the accelerating switching of Norwegian imports towards low cost countries in the wake of the financial crisis. The slower recovery of the measures based on GDP weights can in part be attributed to the same switch, but in this case the effect of relatively high inflation in the low cost countries dominates.

Table 4 shows calculated average annual rates of nominal return, price inflation and real return of the GPFG over the sample period, based on both percentage change from the *previous* year with annual data and percentage change *through* the year (GIPS) with monthly data when available. All calculated average annual rates are measured in both corresponding currency baskets and in NOK.

Table 4 . GPFG. Nominal return, price inflation and real return. Annual average in per cent.[1] 1998-2012

Deflator name	Currency/ Country[8]	Weights[9]	Prices	Nominal return	Price Inflation	Real return[10]	Deviation from present deflator[11]
			Percentage change from the previous year[2]				
CPI_GPFG*[4]	I36	GPFG	CPI	4.7	2.0	2.6	0.0
CPI_GPFG*[4]	NOK	GPFG	CPI	3.8	1.1	2.6	0.0
CPI_GPFG[5]	I36	GPFG	CPI	4.7	1.9	2.8	0.1
CPI_GPFG[5]	NOK	GPFG	CPI	3.8	1.0	2.8	0.1
GDP_GDP[5]	I18	GDP	GDP defl.	5.3	2.8	2.4	–0.2
GDP_GDP[5]	NOK	GDP	GDP defl.	3.8	1.4	2.4	–0.2
CPI_GDP[5]	I18	GDP	CPI	5.3	2.9	2.3	–0.3
CPI_GDP[5]	NOK	GDP	CPI	3.8	1.4	2.3	–0.3
CPI_IMP[5]	I20	Import20	CPI	4.8	2.4	2.4	–0.3
CPI_IMP[5]	NOK	Import20	CPI	3.8	1.4	2.4	–0.3
EXP_IMP[5]	I20	Import20	Export price	4.8	1.4	3.3	0.7
EXP_IMP[5]	NOK	Import20	Export price	3.8	0.5	3.3	0.7
Importdefl[6]	I44	Import44	Import price	5.0	2.6	2.3	–0.4
Importdefl[6]	NOK	Import44	Import price	3.8	1.5	2.3	–0.4
CPI_IMP_CH[7]	I20	Import20	CPI	4.8	1.2	3.5	0.9
CPI_IMP_CH[7]	NOK	Import20	CPI	3.8	0.3	3.5	0.9
EXP_IMP_CH[7]	I20	Import20	Export price	4.8	0.3	4.5	1.8
EXP_IMP_CH[7]	NOK	Import20	Export price	3.8	–0.6	4.5	1.8
			Percentage change through the year[3]				
CPI_GPFG*[4]	I36	GPFG	CPI	5.05[12]	1.94[13]	3.05	0.0
CPI_GPFG*[4]	NOK	GPFG	CPI	4.27	1.18	3.05	0.0
CPI_GPFG[5]	I36	GPFG	CPI	5.1	1.8	3.2	0.1
CPI_GPFG[5]	NOK	GPFG	CPI	4.3	1.1	3.2	0.1
CPI_IMP[5]	I20	Import20	CPI	5.0	2.2	2.8	–0.3
CPI_IMP[5]	NOK	Import20	CPI	4.3	1.4	2.8	–0.3
CPI_IMP_CH[7]	I20	Import20	CPI	5.0	0.9	4.1	1.0
CPI_IMP_CH[7]	NOK	Import20	CPI	4.3	0.2	4.1	1.0

Notes: [1] Geometric mean. [2] Based on annual averages. [3] Based on GIPS and monthly data, see Section 3. [4] Based on equation (8) and CPI's in local currencies. [5] Based on the Törnqvist price index formula, equation (4). [6] Based on unit prices and the Paasche price index formula. [7] Based on the geometric average of price *levels*, equation (11). [8] I18, I20 and I36 denote currency baskets (calculated by the geometric Laspeyres price index) corresponding to the number of countries included in the weighting schemes based on GDP, imports and GPFG investments, respectively, whereas I44 denote the import weighted currency basket based on the 44 main trading partners of Norway. [9] GPFG, GDP, Import20 and Import44 denote the GPFG countries, the 18 largest economies in the world measured by GDP, the 20 largest origin countries of Norway's imports and the 44 largest origin countries of Norway's imports, respectively. [10] Based on the Fisher equation (ex post), equation (2), not taking into account the management costs of the fund. [11] The present deflator defined by means of CPI's and GPFG weights and aggregated by equation (8). Deviation measured in percentage points and rounded off to one decimal place. [12] Official figure, see NBIM (2013). [13] The official figure of 1.92 per cent is based on quarterly data rather than monthly data as in this paper. The official estimate of real return is then 3.07 per cent, and 2.97 per cent taking into account management costs of the fund, see NBIM (2013).

Applying yearly data, we see that nominal return and inflation in all cases are about 1 percentage point lower when measured in NOK than in corresponding currency baskets. Nominal return (just like inflation) is highest when measured by the currency basket corresponding to the countries included in the weighting scheme based on GDP (labelled I18). Likewise, nominal return is lowest when measured by the currency baskets corresponding to the countries included in the weighting schemes based on GPFG investments or imports (labelled I36 and I20, respectively). Our calculations show that the deflators based on consumer prices and GPFG weights deliver estimates of real return of 2.6 and 2.8 per cent compared to 2.3 – 2.4 per cent using the deflators based on consumer prices and import weights, consumer prices and GDP weights and GDP deflators and GDP weights. Most of the gap between these estimates of real return can, as previously noted, be attributed to lower measured inflation using GPFG weights, as a number of high inflation countries are left out compared to the weighting schemes based on GDP and imports. The import deflator from the Norwegian national accounts also produces an estimate of real return of 2.3 per cent. Introducing the relatively slow growing deflator based on export prices and import weights increases the estimate of real return by 0.7 percentage points compared to the estimate of real return based on the current deflator and between 0.5 and 1 percentage points compared to the other alternatives. Accounting for the China effect increases the estimate of real return by yet an additional percentage point, to 4.5 per cent.

Applying the GIPS method with consumer prices, GPFG weights and import weights, which are the only international prices and weighting schemes available for all relevant countries in our study on a monthly basis, produces estimates of average annual real return about 0.5 percentage points higher than the corresponding estimates based on yearly data. This is due to differences in periodicity. The sample period of the GIPS based measures goes from December 1997 to December 2012, which is 15 years altogether. This way, the monthly, GIPS based measures include developments *throughout* the two years of 1998 and 2012, which are two years of high real return. In contrast, the sample period for the annual data, running from average 1998 to average 2012, sums to 14 years, and fails to capture completely the high real return in the first and final years of the sample. Nevertheless, we find that reasonable measures of the deflator of the GPFG deliver a wide range of estimates of the real return, from 2.3 to 4.5 per cent during the sample period.

6. Conclusions

In this paper, we have presented estimates of the *real* return of the GPFG based on alternative measures of the deflator using combinations of different international price measures, weighting schemes and methods of aggregation. International price developments are proxied by foreign consumer prices, export prices and GDP deflators. Weighting schemes are based on the investment shares of the GPFG, the import shares of Norway's main trading partners and the GDP shares of the most important countries in the world economy. We have paid particular attention to measures of the deflator based on CPI’s and GPFG weights, CPI’s and import weights, CPI’s and GDP weights, GDP deflators and GDP weights and export prices and import weights. Based on index number theory, we have aggregated these combinations of international prices and weighting schemes by means of the Törnqvist price index as the underlying aggregator formula. We have also applied the geometric Paasche and Laspeyres price indices to shed light on substitution bias in our empirical context. For comparison, we have presented the deflator of total Norwegian imports of goods and services from the national accounts as an alternative measure of the deflator of the GPFG. Inspired by the empirical literature on the China effect, we have also calculated measures of the deflator by means of geometric averages of price *levels*, thus leaving the ground of classical index number theory. All measures of the deflator in this paper, and thereby of the real return of the GPFG, are based on data running from 1998 to 2012 and measured in corresponding currency baskets and in NOK.

Generally, the choice of international price measure, weighting scheme, index number formula and currency of measurement has significant impact on the calculated deflator. Applying yearly data, our calculations indicate that the deflator based on CPI’s and GDP weights exhibits the highest average annual inflation of 2.9 per cent over the sample period, whereas the deflator based on export prices and import weights exhibits the lowest average annual inflation of 1.4 per cent, both measured in corresponding currency baskets. Measured in NOK the respective figures are 1.4 and 0.5 per cent. The deflator, based on CPI’s and GPFG weights, delivers average annual inflation of 2.0 and 1.1 per cent when measured in the corresponding currency basket and in NOK, respectively. That the deflator based on CPI’s and GDP weights delivers the highest inflation can mainly be explained by the fact that a number of high inflation countries, Russia and China in particular, are included in the weighting scheme. Similarly, the deflator based on export prices and import weights exhibits the lowest inflation because export prices have increased relatively slow, probably due to strong international competition. Accounting for the China effect, we find that the average annual inflation is reduced further by around one percentage point to only 0.3 per cent, and even to deflation of 0.6 per cent when measured in the corresponding currency basket and in NOK, respectively. The China effect is thus of major importance in our empirical case, assuming that purchasing power parity adjusted GDP relative price levels are reasonable proxies to relative price levels on tradable goods. By way of contrast, the comparable figures provided by the import deflator from the Norwegian national accounts are 2.6 and 1.5 per cent. Even though the import deflator in principle should capture the China effect through the use of unit prices of homogenous products across countries, it may in practice underestimate the China effect and overestimate inflation to the extent that quality differences are not properly accounted for following the switch in imports from high cost to low cost countries.

Although currency of measurement is of major importance for the magnitude of the deflator, this is not the case for estimates of *real* return as differences in inflation stemming from the currency of measurement are mirrored in the related estimates of nominal return. We present estimates of average annual *real* return of the GPFG ranging from 2.3 to 3.3 per cent, and up to 4.5 per cent when the China effect is accounted for. The present practice of calculating the deflator based on CPI's and GPFG weights delivers an estimate of average annual *real* return which is close to the middle of this range.

We emphasise that the analyses in this paper have been based on aggregated international prices of different countries. Empirical studies on Norwegian data find, however, that the China effect has been particularly large for certain consumer groups, clothing being one important example. Because the price formation seems to vary considerably across consumer goods, we may calculate measures of the deflator based on disaggregated international prices on various consumer groups in different countries. In this way, we could account for the composition of both consumer goods and countries in the measures of the deflator, which would probably provide better estimates of inflation than estimates based on aggregated international prices. We leave this disaggregated approach for future research.

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Appendix

A.1 The Divisia approach and the connection to economic theory

The exposition of the Divisia approach and the connection to consumer theory in this appendix largely builds on ILO (2005, p. 258 and Appendix 15.4). The Divisia approach assumes that the aggregate value of the consumer expenditure at time t, say $V(t)$, on n commodities belonging to a specific economic aggregate of interest can be written as a product of a time t price level function, say $P(t)$, and a time t quantity level function, say $Q(t)$, such that $V(t) = P(t) \cdot Q(t)$. Assuming that $P(t)$ and $Q(t)$ are differentiable with respect to time leads to the logarithmic value derivative, $V'(t)/V(t)$, which is given by

$$\text{(A1)} \qquad \frac{V'(t)}{V(t)} = \frac{P'(t)}{P(t)} + \frac{Q'(t)}{Q(t)}.$$

The Divisia approach then defines the logarithmic rate of change of the aggregate price level, $P'(t)/P(t)$, and the logarithmic rate of change of the aggregate quantity level, $Q'(t)/Q(t)$, as

$$\text{(A2)} \qquad \begin{aligned} \frac{P'(t)}{P(t)} &\equiv \sum_{i=1}^{n} s_i(t) \frac{p'_i(t)}{p_i(t)} \\ \frac{Q'(t)}{Q(t)} &\equiv \sum_{i=1}^{n} s_i(t) \frac{q'_i(t)}{q_i(t)}, \end{aligned}$$

where

$$\text{(A3)} \qquad s_i(t) \equiv \frac{p_i(t) \cdot q_i(t)}{\sum_{i=1}^{n} p_i(t) \cdot q_i(t)},$$

is the expenditure share of commodity i at time t and $p_i(t)$ and $q_i(t)$ are prices and quantities regarded as continuous functions of time, for i=1,…,n.[26] The definitions in (A2) are known as the Divisia price and quantity *indices*, respectively. The connection between the Divisia approach and consumer theory builds on the assumption that the consumer has well-defined preferences over different combinations of the n commodities represented by the vector $q = (q_1,\dots,q_n)$. The consumer's preferences over alternative possible vectors q are then assumed to be represented by a continuous, non-decreasing and concave utility function f. It is further assumed that the consumer minimizes the cost of achieving the period t utility level, $u^t \equiv f(q^t)$, for periods t=0,1,…,T. Thus, the consumption vector q^t solves the following period t cost minimizing problem:

(A4) $$C(u^t, p^t) \equiv \min_q \left\{ \sum_{i=1}^{n} p_i^t q_i : f(q) = u^t = f(q^t) \right\} = \sum_{i=1}^{n} p_i^t q_i^t ; t = 0,1,...,T,$$

where p^t is the period t price vector for the n commodities that the consumer faces. The solution to (A4) defines the consumer's expenditure or cost function, $C(u^t,p^t)$. Assuming that f is linearly homogenous for strictly positive quantity vectors, $C(u,p)$ decomposes into $uc(p)$ where $c(p)$ is the consumer's *unit* cost function. Hence, the period t total expenditure on the n commodities in the aggregate is given by

(A5) $$\sum_{i=1}^{n} p_i^t q_i^t = c(p^t) f(q^t), t = 0,1,...,T,$$

where the period t unit cost, $c(p^t)$, can be identified as the period t price level, P^t, and the period t level of utility, $f(q^t)$, can be identified as the period t quantity level, Q^t. The price level for period t, $P^t \equiv c(p^t)$, is now related to the Divisia price level, $P(t)$, by assuming that the prices are being continous, differentiable functions of time, say $p_i(t)$, for i=1,…,n. Thus, the unit cost function may also be regarded as a function of time, such that

(A6) $$c^*(t) \equiv c[p_1(t), p_2(t),..., p_n(t)].$$

The logarithmic derivative of $c^*(t)$ is defined by

(A7) $$\frac{d \ln c^*(t)}{dt} \equiv \frac{1}{c^*(t)} \frac{dc^*(t)}{dt} = \frac{\sum_{i=1}^{n} c_i[p_1(t), p_2(t),..., p_n(t)] p'_i(t)}{c_i[p_1(t), p_2(t),..., p_n(t)]},$$

where $c_i[p_1(t), p_2(t),..., p_n(t)] \equiv \partial c[p_1(t), p_2(t),..., p_n(t)] / \partial p_i$ is the partial derivative of the unit cost function with respect to the ith price, p_i, and $p'_i(t) \equiv dp_i(t)/dt$ is the time derivative of the ith price function, $p_i(t)$. Using Shephard's Lemma, the consumer's cost minimizing demand for commodity i at time t is

(A8) $$q_i(t) = u(t) c_i[p_1(t), p_2(t),..., p_n(t)],$$

where the utility level at time t is $u(t) = f[q_1(t), q_2(t),..., q_n(t)]$. The continuous time counterpart to (A5) is that total expenditure at time t is equal to total cost at time t, which in turn is equal to the utility level, $u(t)$, times the period t unit cost, $c^*(t)$, such that

[26] See ILO (2005, p. 258) for a complete derivation of (A2).

(A9) $\sum_{i=1}^{n} p_i(t)q_i(t) = u(t)c^*(t) = u(t)c([p_1(t), p_2(t),..., p_n(t)].$

Using (A7), (A8) and (A9), the logarithmic derivative of the Divisia price level, *P*(*t*), can be defined as

(A10) $\frac{P'(t)}{P(t)} \equiv \frac{c^{*}{}'(t)}{c^*(t)},$

which means that *P*(*t*) under the continuous time cost minimizing assumptions underlying (A4) is equal to the unit cost function evaluated at the time *t* prices, $c^*(t)$, given in (A6). Then from (A5), it follows that the Divisia quantity level, *Q*(*t*), is equal to the consumer's utility function regarded as a function of time, $f^*(t) \equiv f[q_1(t), q_2(t),\ldots, q_n(t)]$. Under the assumption that the consumer is continuously minimizing the cost of achieving a given utility level where the utility or preference function is linearly homogenous, we have shown that the Divisia price and quantity levels have strong connections to economic theory.

A.2 The quadratic approximation lemma

Assuming a quadratic function, $Y(t)=f\left(X(t),Z(t)\right)$, the quadratic approximation lemma (Diewert, 1976) says that

(A11) $$\Delta Y(t)=\overline{f'_{Z(t)}}\Delta Z(t)+\overline{f'_{X(t)}}\Delta X(t),$$

where

(A12) $$\begin{aligned}\overline{f'_{Z(t)}}&=\frac{1}{2}\left(f'_{Z(t)}+f'_{Z(t-1)}\right)\\ \overline{f'_{X(t)}}&=\frac{1}{2}\left(f'_{X(t)}+f'_{X(t-1)}\right)\end{aligned}$$

The starting point in our case is the natural logarithms of the geometric average of price *levels* in (10) in the text, assuming two countries for simplicity, to obtain

(A13) $$\ln P(t)=s_1(t)\ln p_1(t)+s_2(t)\ln p_2(t).$$

Hence, $Y(t)=f\left(X(t),Z(t)\right)$ is in our case given by $Y(t)=X_1(t)\cdot Z_1(t)+X_2(t)\cdot Z_2(t)$, where $Y(t)=\ln P(t), X_1(t)=s_1(t), Z_1(t)=\ln p_1(t), X_2(t)=s_2(t), Z_2(t)=\ln p_2(t)$, and (A11) is equal to

(A14) $$\Delta\ln P(t)=\overline{f'_{\ln p_1(t)}}\Delta\ln p_1(t)+\overline{f'_{s_1(t)}}\Delta s_1(t)+\overline{f'_{\ln p_2(t)}}\Delta\ln p_2(t)+\overline{f'_{s_2(t)}}\Delta s_2(t),$$

where

(A15) $$\begin{aligned}\overline{f'_{\ln p_1(t)}}&=\frac{1}{2}\left(f'_{\ln p_1(t)}+f'_{\ln p_1(t-1)}\right)=\frac{1}{2}\left(s_1(t)+s_1(t-1)\right),\\ \overline{f'_{s_1(t)}}&=\frac{1}{2}\left(f'_{s_1(t)}+f'_{s_1(t-1)}\right)=\frac{1}{2}\left(\ln p_1(t)+\ln p_1(t-1)\right),\\ \overline{f'_{\ln p_2(t)}}&=\frac{1}{2}\left(f'_{\ln p_2(t)}+f'_{\ln p_2(t-1)}\right)=\frac{1}{2}\left(s_2(t)+s_2(t-1)\right),\\ \overline{f'_{s_2(t)}}&=\frac{1}{2}\left(f'_{s_2(t)}+f'_{s_2(t-1)}\right)=\frac{1}{2}\left(\ln p_2(t)+\ln p_2(t-1)\right).\end{aligned}$$

Then, it follows from (A15) that

(A16) $$\begin{aligned}\Delta\ln P(t)=&\frac{1}{2}\left(s_1(t)+s_1(t-1)\right)\Delta\ln p_1(t)+\frac{1}{2}\left(\ln p_1(t)+\ln p_1(t-1)\right)\Delta s_1(t)\\ &+\frac{1}{2}\left(s_2(t)+s_2(t-1)\right)\Delta\ln p_2(t)+\frac{1}{2}\left(\ln p_2(t)+\ln p_2(t-1)\right)\Delta s_2(t).\end{aligned}$$

Using the summing up conditions, $s_2(t)=\left(1-s_1(t)\right), \Delta s_2(t)=-\Delta s_1(t)$, we get

(A17) $$\Delta \ln P(t) = \overline{s_1(t)} \Delta \ln p_1(t) + \left(1 - \overline{s_1(t)}\right) \Delta \ln p_2(t) + \Delta s_1(t)\left(\overline{\ln p_1(t)} - \overline{\ln p_2(t)}\right),$$

where

(A18) $$\overline{s_1(t)} = \frac{1}{2}\left(s_1(t) + s_1(t-1)\right),$$
$$\overline{\ln p_1(t)} = \frac{1}{2}\left(\ln p_1(t) + \ln p_1(t-1)\right),$$
$$\overline{\ln p_2(t)} = \frac{1}{2}\left(\ln p_2(t) + \ln p_2(t-1)\right).$$

A.3 Decomposing the China effect

We may decompose the term $\Delta s_1(t)\left(\overline{\ln p_1(t)} - \overline{\ln p_2(t)}\right)$ from (11) in the text by first using (A17) and (A18) to observe that

(A19)
$$\begin{aligned}\Delta s_1(t)\left(\overline{\ln p_1(t)} - \overline{\ln p_2(t)}\right) &= \Delta s_1(t)\left[\frac{1}{2}\left(\ln p_1(t) + \ln p_1(t-1)\right) - \frac{1}{2}\left(\ln p_2(t) + \ln p_2(t-1)\right)\right] \\ &= \frac{1}{2}\Delta s_1(t)\left[\left(\ln p_1(t) - \ln p_2(t)\right) + \left(\ln p_1(t-1) - \ln p_2(t-1)\right)\right] \\ &= \frac{1}{2}\Delta s_1(t)\left[\ln\left(\frac{p_1(t)}{p_2(t)}\right) + \ln\left(\frac{p_1(t-1)}{p_2(t-1)}\right)\right].\end{aligned}$$

We then have that

(A20) $$\frac{p_1(t)}{p_2(t)} = \frac{p_1(0)}{p_2(0)} \cdot \frac{I_1(t)}{I_2(t)}, \forall t$$

where

(A21)
$$\begin{aligned}I_1(t) &= \frac{p_1(t)}{p_1(0)}, \\ I_2(t) &= \frac{p_2(t)}{p_2(0)},\end{aligned}$$

are price *indices* and $p_1(0)$ and $p_2(0)$ are price *levels* in period zero in country 1 and country 2, respectively. Now, inserting (A20) and (A21) into (A19), we obtain after some intermediate derivations

(A22) $$\Delta s_1(t)\left(\overline{\ln p_1(t)} - \overline{\ln p_2(t)}\right) = \Delta s_1(t)\left[\ln\left(\frac{p_1(0)}{p_2(0)}\right) + \frac{1}{2}\ln\left(\frac{p_1(t)}{p_1(0)} \cdot \frac{p_1(t-1)}{p_1(0)}\right) - \frac{1}{2}\ln\left(\frac{p_2(t)}{p_2(0)} \cdot \frac{p_2(t-1)}{p_2(0)}\right)\right],$$

or

(A23) $$\Delta s_1(t)\left(\overline{\ln p_1(t)} - \overline{\ln p_2(t)}\right) = \Delta s_{1t}\left[\ln\left(\frac{p_1(0)}{p_2(0)}\right) + \overline{\Delta \ln p_1(t,0)} - \overline{\Delta \ln p_2(t,0)}\right],$$

where

(A24)
$$\begin{aligned}\overline{\Delta \ln p_1(t,0)} &= \frac{1}{2}\left(\Delta \ln p_1(t,0) + \Delta \ln p_1(t-1,0)\right), \\ \overline{\Delta \ln p_2(t,0)} &= \frac{1}{2}\left(\Delta \ln p_2(t,0) + \Delta \ln p_2(t-1,0)\right).\end{aligned}$$

A.4 Chained and fixed base period indices

The price indices presented in Section 2.2 are so-called bilateral price indices as the underlying index number formula depends *only* on the price and quantity data for the two periods for which prices are being compared. When there are more than two time periods involved in a price comparison, it is an important empirical issue to consider whether to use chained or fixed base period price indices. The Divisia price index may be viewed as a theoretical rationale for chaining the bilateral price indices in (4) and (5) in the text, see e.g. Trivedi (1981). Chaining of index numbers is nothing but a multiple of bilateral indices. That is, at every new period, the previous period is chosen 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). Thus, chaining of the Törnqvist price index generates the following pattern of index numbers for the first three periods 0, 1 and 2:

(A25) $1, \mathrm{P}^{\mathrm{T}}(p^0, p^1, q^0, q^1), \mathrm{P}^{\mathrm{T}}(p^0, p^1, q^0, q^1) \cdot \mathrm{P}^{\mathrm{T}}(p^1, p^2, q^1, q^2).$

In contrast, the fixed base period Törnqvist price index simply computes the level of prices in each period relative to the base period 0, such that the pattern of index numbers for the first three periods is

(A26) $1, \mathrm{P}^{\mathrm{T}}(p^0, p^1, q^0, q^1), \mathrm{P}^{\mathrm{T}}(p^0, p^2, q^0, q^2).$

The choice between a fixed base price index and a chained price index will generally depend on the length of the time series considered and the degree of variation in the prices and quantities from period to period. The more prices and quantities are subject to large fluctuations (rather than smooth trends), the more divergence between a fixed price index and a chained price index, see e.g. Diewert (1978) and Hill (1988). However, when employing a fixed price index, base period dependency appears and one should carefully consider which base period to choose. For time series with smooth trends it will not matter much whether a fixed base period index or a chained index is calculated, as long as the symmetrically weighted Fisher, Walsh and Törnqvist price indices are the underlying index number formulas, ILO (2005, p. 283). In this paper, we chain the bilateral indices by means of (A25).

A.5 Data definitions, sources (in parenthesis) and availability

The sample period is 1998-2012. All data are annual averages, except for the GIPS calculations which are based on monthly data running from December 1998 to December 2012.[27] The deflators are calculated in a corresponding currency basket and in NOK, and aggregated by the geometric Laspeyres, Paasche and Törnqvist price index number formulas. Data for international prices and weights are from the OECD Economic Outlook (OECD EO) and International Monetary Fund World Economic Outlook (IMF WEO) databases, where comparability across countries is an important objective. The OECD EO database is updated in June and December, and is also available on a quarterly basis. The IMF WEO database is updated in April and October, and is annual only, but the corresponding data series are generally available on a quarterly basis, and CPI data on a monthly basis, from the individual national statistical offices. The foreign exchange rate data are from Macrobond, and are available also at a daily frequency. The data for GPFG weights, nominal return and the corresponding currency basket are made available to us at a monthly basis by The Ministry of Finance. Norwegian import weights are based on data from the foreign trade statistics at Statistics Norway, available on a monthly basis. The import deflator from the Norwegian national accounts is available from Statistics Norway at a quarterly basis. Purchasing power parity adjusted GDP relative price levels are from Penn World Tables at an annual basis. The deflators discussed in this paper are listed below:

- CPI and GPFG weights: CPI's aggregated by the geometric Törnqvist, Paasche and Laspeyres price index number formulas, the latter (for small price changes) consistent with the definition of the present deflator of the GPFG, weighted according to the share of each country in the benchmark index of the GPFG and measured in a corresponding currency basket and in NOK
    - GPFG weights: Including all 36 countries in the benchmark index of the GPFG, the euro area counting as one country, as country specific data for the euro area was not available to us for the full sample period. The countries included are, in order of importance in 2011; United States, euro area, United Kingdom, Japan, Switzerland, Canada, Australia, Sweden, Hong Kong, South Korea, Denmark, Mexico, Brazil, Russia, Taiwan, South Africa, Poland, Singapore, India, Malaysia, Turkey, Thailand, Chile, Czech Republic, Indonesia, New Zealand, Philippines, Hungary, Peru, Israel, Colombia, Egypt, United Arab Emirates, Pakistan, Morocco and Argentina. (Norges Bank).
    - CPI (IMF WEO)
    - Corresponding currency basket (Norwegian Ministry of Finance)

[27] The monthly data are defined as monthly averages for CPI's and import weights, and the final day of each month for exchange rates, GPFG weights and nominal return on the GPFG.

- GDP deflators and GDP weights: GDP deflators aggregated by the Törnqvist price index and the geometric Laspeyres and Paasche price index number formulas, weighted according to each country's share of global GDP and measured in a corresponding currency basket and in NOK
    - GDP weights: Each country's GDP (value) as a share of global GDP (value). Including all 18 countries with a share above 1 per cent of global GDP in 2011. The countries included are, in order of importance in 2011; United States, China, Japan, Germany, France, Brazil, United Kingdom, Italy, Russia, India, Canada, Australia, Spain, Mexico, South Korea, Indonesia, Netherlands and Turkey (IMF WEO)
    - GDP deflators (IMF WEO)
    - Corresponding currency basket: Bilateral NOK exchange rates (Macrobond) aggregated by the geometric Laspeyres index number formula and GDP weights (IMF WEO)

- CPI's and GDP weights: CPI's aggregated by the Törnqvist price index number formula, weighted according to each country's share of global GDP and measured in a corresponding currency basket and in NOK
    - GDP weights, CPI's and corresponding currency basket as above

- CPI and import weights: CPI's aggregated by the Törnqvist price index and the geometric Laspeyres and Paasche price index number formulas, weighted according to each country's share of Norwegian imports and measured in a corresponding currency basket and in NOK
    - Import weights: Norwegian imports of goods (value) from each country as a share of total Norwegian imports (value). Including all 20 countries with a share above 1 per cent of Norway's imports in 2011. The countries included are, in order of importance in 2011; Sweden, Germany, China, Denmark, United Kingdom, USA, Netherlands, Canada, France, South-Korea, Poland, Italy, Finland, Japan, Russia, Spain, Belgium, Brazil, Switzerland and Check Republic (foreign trade statistics, Statistics Norway. Available on a monthly basis)
    - CPI as above
    - Corresponding currency basket: Bilateral NOK exchange rates (Macrobond) aggregated by the geometric Laspeyres index number formula and import weights (foreign trade statistics, Statistics Norway)
    - Additional data in the case where the China effect is accounted for: purchasing power parity adjusted GDP relative price levels (Penn World Tables)

- Export prices and import weights: Export prices are aggregated by the Törnqvist price index and the geometric Laspeyres and Paasche price index number formulas, weighted according to each country's share of Norwegian imports and measured in a corresponding currency basket and in NOK
    - Import weights: as above
    - Export prices: Deflator of exports of goods and services based on National Accounts (OECD EO). Export prices are not available for Russia. CPI from IMF WEO is used as a proxy
    - Corresponding currency basket: as above
    - Additional data in the case where the China effect is accounted for: purchasing power parity adjusted GDP relative price levels (Penn World Tables)

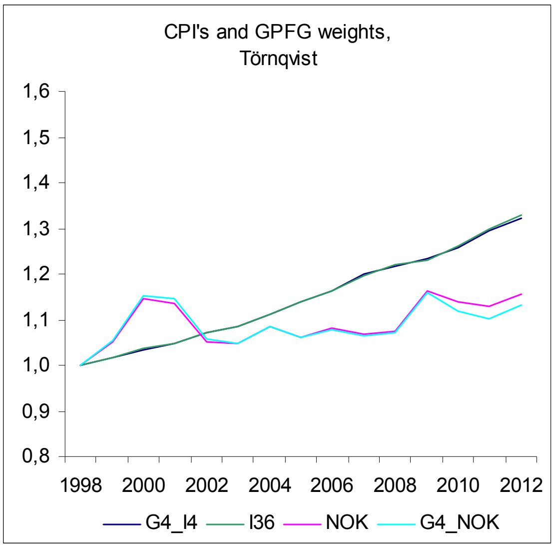
- Import deflator (National accounts, Statistics Norway / IMF WEO): Including all Norwegian imports, measured in NOK and converted to a (close to) corresponding currency by the import weighted exchange rate basket including 44 countries covering 97 per cent of Norwegian imports calculated by Norges Bank (geometric Laspeyres index). See Section 3.4 for a more detailed description

Data for nominal return from the GPFG (Norwegian Ministry of Finance/Norges Bank) are combined with the deflators and currency baskets above in order to calculate alternative rates of real return of the GPFG.

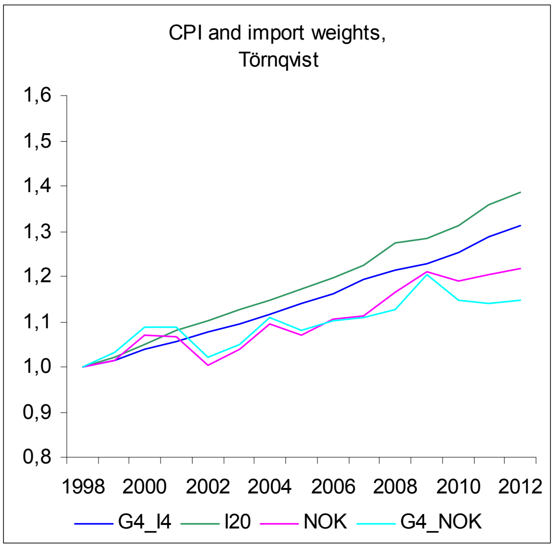
A.6 Reducing the number of countries

The present deflator of the GPFG, based on consumer prices and GPFG weights, consists of up to 36 currencies in the sample period, including the euro. It could be of interest to investigate the loss of information by reducing the number of countries in the calculations of some of the measures of the deflator. Figure A displays the deflators based on consumer prices and GPFG weights (Panel a), consumer prices and import weights (Panel b) and GDP deflators and GDP weights (Panel c), all of which are calculated by means of the Törnqvist price index and the aggregate consisting of the four major OECD economies of USA, euro area, Japan and Great Britain (labelled G4), and measured in the corresponding currency baskets and in NOK. In addition, Figure A displays the deflator based on export prices and import weights including the China effect (Panel d), measured in corresponding currency baskets and in NOK.

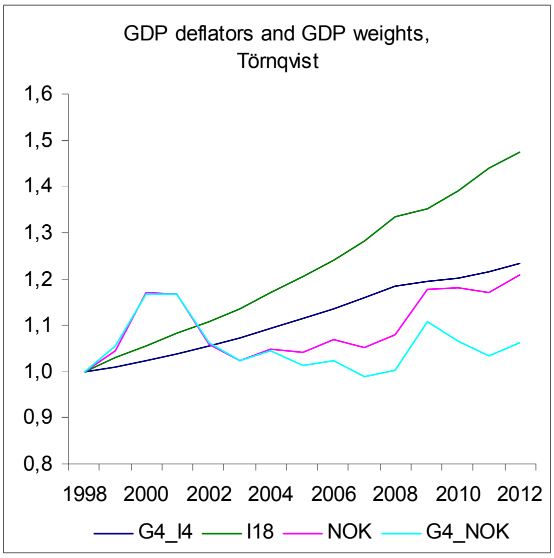
Figure A. Deflators based on the G4 aggregate (1998=1)



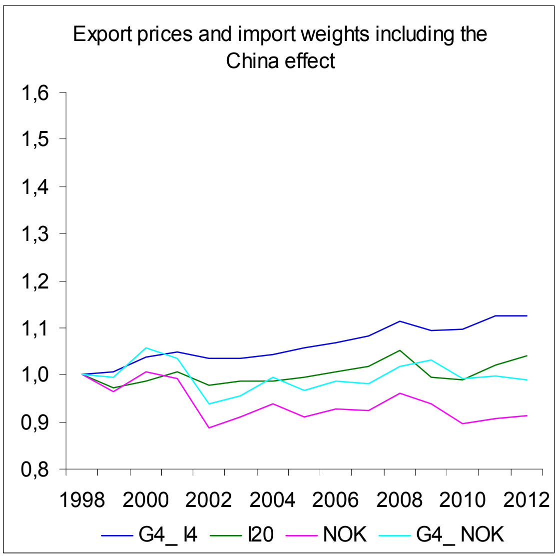
Panel a



Panel b



Panel c



Panel d

We see that a reduction to these four currencies, which constitutes around 80 per cent of GPFG investments, has minor consequences for the calculated deflator based on consumer prices and GPFG weights, although there is an increasing gap towards the end of the sample period (Panel a). However, employing the G4 aggregate has wider consequences for the calculated deflator based on import weights and GDP weights, as the euro area, USA, UK and Japan together constituted just 40 and 50 per cent of world GDP and Norwegian imports respectively in 2012. Accordingly, leaving out a number of high inflation countries provides a *lower* estimate of inflation as defined by the deflator based on CPI's and import weights and the deflator based on GDP deflators and GDP weights (Panel b and c respectively). When we account for the China effect, however, leaving out the deflationary China effect of the low cost countries dominates the effect of leaving out the relatively high inflation of the same countries, so that the G4 aggregate provides a relatively *high* estimate of inflation (Panel d).