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MEASURING INFLATION

HISTORY, THEORY, APPLICATIONS AND IMPORTANCE

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Abstract

Sweden and other western economies have been battling low rates of inflation since the economic crisis of 2008. However, the Swedish economy is booming, with soaring house prices and falling rate of unemployment which got us to wonder how these phenomenon's could be observed at the same time. We therefore conducted a thorough investigation of what inflation actually is and how it is measured. We found that different types of consumer price indexes where the most widely used approach to measure inflation, with the Laspeyres method of computing indexes as the most prominent. Furthermore, the way of measuring inflation differs from country to country, where the most significant distinctions between Sweden's KPI and the Eurozone-countries generalized HICP, is that costs attributed to housing are omitted in the HICP. In the light of these findings we came to the conclusion that the lack of high rate of inflation in Sweden, even when the economy is booming, might not be as extraordinary as we first expected.

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Background and introduction

The world economy has far from recovered since the financial crisis of 2007-2009. Although its causes are complex with a property bust in the United States at the center (The Economist 2014), the crisis started when the American authorities declined to bail out Lehman Brothers, the fourth largest investment bank in the country. Amid the resulting financial confusion, non-financial companies could no longer rely on being able to borrow to pay suppliers and employees. The outcome was a freeze on spending and hoarding of cash, resulting in a seizure in the real economy. Eventually, the crisis spread to Europe. Furthermore, here it was exacerbated by the exposure of economic imbalances within the European Monetary Union (EMU), with North European current account surpluses financing South European current account deficits. The turmoil almost blew the infant Eurozone apart, and it took a declaration in July 2012 from Mario Draghi, the head of the European Central Bank, to calm markets down; he stated that "it would do what it takes" to help countries out (Euronews 2012). The crisis is far from over, however, and now it is not only the euro project which is in jeopardy: the current refugee crisis is calling into question the Schengen agreement - the free movement of people within Europe - and with the possibility of a British exit from the European Union in a referendum, the existence of the union itself is at stake.

In the aftermath of the financial crisis, low inflation rates are tormenting the central bankers of the rich world. The ghost hovering above their heads is *The Great Depression*: a long period of extreme economic hardship, which was precipitated by a stock market crash on October 29 1929 and then exacerbated - in retrospect - by an erroneous tight monetary policy resulting in a damaging deflationary spiral (Whaples 1995). The central bankers of today are eager not to repeat the mistake of the past and have therefore - in order to keep inflation rates on the positive side - not only lowered their discount rates to zero levels (occasionally sub-zero), but also been engaged in massive purchases of assets, so called *quantitative easing* (QE), an extreme form of loose monetary policy. Some central banks have also resorted to interventions on the currency market with the aim to weaken the exchange rates of their currencies. The plan is that exports, economic output and thereby inflation will increase; alternatively, higher import prices will lead to "imported" inflation. Sweden has not been an exception from the course of events described above.

However, despite an inflation level far below the target, on the surface it currently looks as if the economy is doing well: the economic growth is respectable; the unemployment, although not everyone would agree, is not too high; and there is optimism about the future as judged by most forecast indicators. Furthermore, the housing market is booming with property prices soaring. There is a consensus among economists that deflation is a bad thing: expectations of falling prices should lead to postponed purchases (lower demand) which would lead to ever lower prices; a deflationary spiral (Hummel 2007). There are currently no signs of this in Sweden. Why is that? Are Swedes insensitive to deflation in their economic behavior? Or is there something in the way deflation is determined which can explain this discrepancy?

All this roused our interest in what inflation really is, how it is measured, and why the measurement of inflation is important. We will treat the questions in that order, with the reservation that the importance of measuring inflation will be handled in order of appearance – there are several factors - and for convenience be summed up at the end of the report.

Inflation - what is it?

Inflation is defined as a sustained increase in the general price level of goods and services in an economy over a period of time (Blanchard 2000). When the price level increases, each unit of currency buys fewer goods and services and thus inflation reflects a decrease in the purchasing power per unit of currency: a loss of real value. Deflation is the opposite to inflation.

Note the word *general* in the definition of the concepts. As we will see, it is perfectly possible that the prices of some goods decrease, while the general price level increases, provided that the impact of the price increases of the other goods is larger. Most people have a sense that the prices of *most* goods and services continually increase: rents, subscription prices, fees etc. seldom decrease. The rate of inflation varies over time. The elder of the authors of this report still has vivid memories from his childhood in the high-inflation 1970s when the weekly allowance - not inflation-adjusted - resulted in ever less candy on Saturdays; not a problem for the youngsters of today. Less clear to most people, perhaps - apart from the fact that everybody wants more for their goods, services and labor all the time - is what actually causes inflation. The history of the origin of inflation also reveals that the present definition of the word has not been the same through the ages, but is rather new (Bryan 1997).

Inflation has occurred in many different societies throughout history (Harl 1996; The Independent 2002). Various metals, notably gold has been used as currency in many countries. In order to finance wars and other costly projects, rulers have not seldom collected coins, melted them down, mixed them with less valuable metals, and reissued them with the same nominal value as before. By this dilution the government could issue more coins without having to increase the amount of valuable metal used to make them. Obviously, when the relative value of each coin became lower, consumers had to give more coins in exchange for the same amount of goods and services: inflation.

Around the 10th century the Song Dynasty in China was the first regime to introduce the printing of paper money in order to create fiat currency (Glahn 1996, p. 48). Later, the Yuan Dynasty fought a number of wars and printed more money to finance them (Ropp 2010, p. 82). This naturally led to inflation, and the problems associated with it were so severe that the following dynasty reverted to using copper coins (Bernholz 2003, pp. 53-55).

In the past, large infusions of gold and silver into an economy has also led to inflation. From the second half of the 15th century to the first half of the 17th century Europe underwent an inflationary cycle referred to as the *price revolution*: prices rose on average perhaps six fold during 50 years (Hamilton 1934; Munro 2003). The reason was the sudden influx of gold and silver from newly found South America into Habsburg Spain and then further throughout Europe (Walton 1994). These causes of inflation are referred to as *change in the price of money*: a variation in the commodity price of the metallic content in the currency.

The second cause of inflation is referred to as *depreciation of the currency*. In the United States during the period between the mid-1830s and the Civil War, the proliferation of private banknotes printed outstripped the quantity of gold available to redeem them.

It was now that the word "inflation" began to appear in the literature, but not in reference to something which happens to prices, but something that happens to paper currency. The relationship between the over-supply of banknotes and a resulting depreciation in their value was noted by classical economists such as David Hume and David Ricardo, who later would examine and debate what effect a currency devaluation (later called *monetary inflation*) has on the price of goods and services (later called *price inflation* and eventually just *inflation*).

The third cause of inflation is referred to as *change in value*, with which is meant the real resource cost of a good.

Thus, a distinction is made between the *real* price (or value) of a good - defined as the effort required to produce it - and the *nominal* (or money) price which is said to be its cost in money alone (fixed in terms of some precious metal). According to this view, the values of goods and services are determined by the effort of labor, while their nominal prices fluctuate with the availability of the precious metal, and the laws of the state that define a nation's money.

The thought that changes in the quantity of money affect only the money price of goods, and not their value, was championed by many of the early classical economists, most notably David Hume. The idea was more rigorously developed in the early 20th century by Irving Fisher and has become known as the *quantity theory of money*.

Keynes (1930) initiated an attack on the quantity theory of money and Keynesian Theory came to dominate macroeconomic thought over the next 40 years. The theory challenged the necessary connection between the quantity of money and the general price level. Furthermore, not only did Keynesian theory separate the price level from the money stock, but it also seems to have separated the word *inflation* from a condition of money and redefined it as a description of prices: inflation became synonymous with any price increase. Today, little distinction is made between a price increase and inflation.

To sum up, *inflation* first referred to a condition of the currency, then to a condition of money, and is now commonly used to describe prices.

Inflation is loved by few: throughout history people have become annoyed when wages have not kept up with rising prices. Various thinkers have come up with ways to deal with inflation. However, in order to treat a condition one needs to know its symptoms. They can be more or less strong and the supreme way to find out how serious is by way of measurement. The established way to measure variations in prices (and thus inflation) is through price indexes.

Consumer price indexes

There are various approaches to consumer price indexes (Diewert 1993, 2001, 2002), and we will cover four of them in approximate order of appearance in the literature: *the fixed-basket approach*, *the stochastic (or statistical) approach*, *the test (or axiomatic) approach*, and *the economic approach*.

The fixed-basket approach

William Fleetwood, the bishop of Ely, created what could perhaps be considered the first true index (Chance 1966; Wirth 1946). In 1707 he was approached by an Oxford student who risked losing his fellowship because of a 15th century rule barring students with annual incomes above 5 pounds; Fleetwood was asked to help show how prices had changed. He proposed an index consisting of averaged price relatives and employed the method to compare the value of money in 1707 and 1406 respectively, using 5 quarters of wheat, 4 hogsheads of beer, and 6 yards of cloth. Later, after a period of substantial inflation, the method was employed by the legislature of Massachusetts to index the pay of soldiers in the Revolutionary War. Here the goods in the basket were corn, beef, sheep's wool, and sole leather (Fisher 1913, pp. 437).

The man who could be considered the father of the consumer price index, however, was Joseph Lowe (1823). He developed the concept considerably by, for example, recognizing that a constant basket of commodities could vary across demographic groups; envisaging a national "table of reference" in the form of a constant national consumption vector at the prices of each year t ; suggesting that the government should fund the collection of the relevant quantity and price statistics.

Lowe proposed various applications for his tables of references:

- Indexing of wages, salaries and rents to compensate for unforeseen fluctuations in the value of the currency
- Facilitating salary negotiations
- Indexing of long-term agricultural leases
- Payment to bondholders in real terms if so desired

Lowe could see a reason why his suggested tables had not already been introduced:

"This has, we believe, been owing to two causes; the unfortunate neglect of political economy in the education of our public men; and the interest of government, the greatest of all debtors, to prevent the public from fixing its attention on the gradual depreciation of money that went on during the half century to the late peace."

(Lowe 1823, Appendix 95)

In the same vein as Lowe, Scrope (1833) somewhat later proposed a comprehensive social security system to help workers incapable of working due to illness, accident or age. The establishment of a tabular standard was also Scrope's key to computing compensation.

All the examples above highlight the first application of a consumer price index: as a cost-of-living index or, alternatively, as a compensation index.

The French economist and statistician Laspeyres (1871) was the first to develop an index number formula method for determining price increases (and implicitly inflation). He simply determined the price of a constant basket of commodities at two different points in time, or *periods*, and defined the price index, P_L , as the price ratio:

$$P_L(p^0, p^1, q^0) \equiv \frac{p^1 q^0}{p^0 q^0} \equiv \frac{\sum_{n=1}^N p_n^1 q_n^0}{\sum_{n=1}^N p_n^0 q_n^0} \quad (\text{eq. 1})$$

where $p^0 = [p_1^0, p_2^0 \dots p_N^0]$ and $p^1 = [p_1^1, p_2^1 \dots p_N^1]$ are price vectors and $q^0 = [q_1^0, q_2^0 \dots q_N^0]$ is a quantity vector; the subscripts 1, ..., n, ...N denote different goods in the basket. Importantly, the quantity vector at period 0, q^0 , is held constant over the two periods. Period 0 is referred to as the base period, while period 1 is referred to as the current period.

The Laspeyres price index formula can be rewritten (details omitted) in a form containing expenditure shares, s_n , of the respective goods instead of quantities. This is much appreciated by price statisticians because expenditure shares are much easier to extract from expenditure data:

$$P_L(p^0, p^1, q^0) = \sum_{n=1}^N s_n^0 (p_n^1 / p_n^0) \quad (\text{eq. 2})$$

where s_n^0 is the expenditure share of good n during period 0.

Note that one computes the index *assuming* that the consumption basket is fixed; in reality, however, it is not. Laspeyres, as we could see, proposed that the base-period vector, $q^0 = [q_1^0, q_2^0 \dots q_N^0]$, should be used (eq. 1), but we could just as well use the consumption basket at period 1 as fixed. Indeed, Paasche (1874) proposed using the current-period vector, $q^1 = [q_1^1, q_2^1 \dots q_N^1]$ and defined the Paasche index, P_P , as:

$$P_P(p^0, p^1, q^1) \equiv \frac{p^1 q^1}{p^0 q^1} \equiv \frac{\sum_{n=1}^N p_n^1 q_n^1}{\sum_{n=1}^N p_n^0 q_n^1} \quad (\text{eq. 3})$$

However, since we are dealing with vector calculations, it does make a difference which one of the two one chooses. It can be shown (Diewert 2002, pp. 49-64) that if there is significant variation in the relative prices, p_n^1/p_n^0 , then the Paasche price index usually will be substantially below the corresponding Laspeyres index.

Given that the quantity vectors would not be exactly equal during the two periods, various authors started to argue that averages of the Laspeyres and the Paasche index should be used as a measure of price change. The *arithmetic mean* of the Laspeyres and Paasche indexes constitute the Drobisch-Sidgwick price index, P_{DS} (Drobisch 1871; Sidgwick 1883):

$$P_{DS}(p^0, p^1, q^0, q^1) = \frac{P_L(p^0, p^1, q^0) + P_P(p^0, p^1, q^1)}{2} \quad (\text{eq. 4})$$

The *geometric mean*, on the other hand, is called the Fisher ideal price index, P_F (Fisher 1922):

$$P_F(p^0, p^1, q^0, q^1) = [P_L(p^0, p^1, q^0) P_P(p^0, p^1, q^1)]^{1/2} \quad (\text{eq. 5})$$

However, instead of finding a best average of two fixed basket indexes as above, one might look for a best average basket of two baskets represented by two vectors q^0 and q^1 , and use that average basket to compare the price levels of period 0 and 1:

$$P_K(p^0, p^1, q^0, q^1) \equiv \frac{\sum_{n=1}^N p_n^1 m(q_n^0, q_n^1)}{\sum_{j=1}^N p_j^0 m(q_j^0, q_j^1)} \quad (\text{eq. 6})$$

where $m(q_n^0, q_n^1)$ is the mean of the quantity of good n purchased in period 0 and 1 respectively. Price statisticians refer to this type of index as a *pure price index* and it also corresponds to Knibbs' unequivocal price index, P_K (Knibbs 1924).

We are now back to the problem of what type of average one should use for the computation. If one chooses the arithmetic mean, one ends up with the Marshall-Edgeworth price index, P_{ME} (Edgeworth 1925; Marshall 1887):

$$P_{ME}(p^0, p^1, q^0, q^1) \equiv \frac{\sum_{n=1}^N p_n^1 \frac{(q_n^0 + q_n^1)}{2}}{\sum_{j=1}^N p_j^0 \frac{(q_j^0 + q_j^1)}{2}} \quad (\text{eq. 7})$$

On the other hand, if one chooses the geometric mean, one obtains the Walsh price index, P_W (Walsh 1901, p. 398) (Walsh 1921, p. 97):

$$P_W(p^0, p^1, q^0, q^1) \equiv \frac{\sum_{n=1}^N p_n^1 (q_n^0 q_n^1)^{1/2}}{\sum_{j=1}^N p_j^0 (q_j^0 q_j^1)^{1/2}} \quad (\text{eq. 8})$$

However, it is better to have an expression where the price index is a function of the expenditure shares for the two periods, s_n^0 and s_n^1 respectively (expenditure shares being much easier to extract from expenditure data), and the price ratios:

$$P_W(p^0, p^1, q^0, q^1) \equiv \frac{\sum_{n=1}^N (s_n^0 s_n^1)^{1/2} [p_n^1 / p_n^0]^{1/2}}{\sum_{j=1}^N (s_j^0 s_j^1)^{1/2} [p_j^1 / p_j^0]^{1/2}} \quad (\text{eq. 9})$$

Which alternative, then, should one choose? Before attempting to answer that question, we present another approach which emerged, and came to be known as *the stochastic or statistical approach*.

The stochastic or statistical approach

The stochastic or statistical approach originated with (Jevons 1865, 1884), who came up with the assumption that increases in the supply of money increase all prices proportionately except for random fluctuations. Note that the concept of "supply of money" now enters the argument. In the words of today, one could say that the basic idea of the stochastic/statistical approach is that each relative price, p_n^1/p_n^0 , can be viewed as an estimate of a common inflation rate, α , between period 0 and 1:

$$\frac{p_n^1}{p_n^0} = \alpha + \varepsilon_n; \quad n = 1, 2, \dots, N \quad (\text{eq. 10})$$

where ε_n are random variables with mean 0 and variance σ^2 .

With additive errors and a sufficient number of independent observations, an appropriate price index could be obtained by taking the arithmetic mean of the price ratios p_n^1/p_n^0 :

$$P(p^0, p^1) = \frac{1}{N} \sum_{n=1}^N \frac{p_n^1}{p_n^0} \quad (\text{eq. 11})$$

On the other hand, with multiplicative errors, an appropriate price index could be obtained by taking the geometric mean of the price ratios. The second alternative was advocated by Jevons, and thus the Jevons index, P_J , was born:

$$P_J(p^0, p^1) \equiv \prod_{n=1}^N (p_n^1/p_n^0)^{1/N} \quad (\text{eq. 12})$$

We now return to the question above from the discussion of the fixed basket approach: which mean, or average, should one use to compute a price index? Which one could be considered to be the "best"? This leads us to the third approach to price indexes, *the test or axiomatic approach*, which emerged in parallel with the stochastic/statistical approach.

The test or axiomatic approach

The early workers in the field now started to compare their own favorite index formula with those of their competitors, and look for benefits and drawbacks. The originator was, once again, Jevons, who recognized that his price index formula (eq. 12) gave index number comparisons between any two years that were independent of the base year. What does this mean? Let $P(p^0, p^t, q^0, q^t)$ be a generic index number formula which compares the level of prices in period t to the level of prices in period 0; p^t and q^t are price and quantity vectors respectively for year t , where $t=0, 1, 2, \dots, T$. If 0 denotes the base year, the level of prices in year t relative to year s is:

$$P(p^0, p^t, q^0, q^t)/P(p^0, p^s, q^0, q^s) \quad (\text{eq. 13})$$

If the base year now is changed to year i , the level of prices in period t relative to period s becomes:

$$P(p^i, p^t, q^i, q^t) / P(p^i, p^s, q^i, q^s) \quad (\text{eq. 14})$$

For these comparisons to be independent of the base year, according to Jevons's wishes, these two numbers must be equal:

$$P(p^0, p^t, q^0, q^t) / P(p^0, p^s, q^0, q^s) = P(p^i, p^t, q^i, q^t) / P(p^i, p^s, q^i, q^s) \quad (\text{eq. 15})$$

This *property*, that the computation of the price index should be independent of the choice of base period, seems to be a very reasonable one and the *test* later came to be known as *the base invariance test*.

Over time sundry properties (or *axioms*) that a price index should fulfil were suggested, and corresponding tests were designed to check their validity. The basic idea behind the axiomatic approach is that an index number formula is seen as some weighted average of the individual relative prices, p_n^1 / p_n^0 . Assume that there is only one commodity. A very reasonable measure of price change between period 1 and period 0 is then p_1^1 / p_1^0 . The test approach asks that the price index $P(p^0, p^1, q^0, q^1)$ satisfy mathematical properties that are analogous to the single commodity price index. More than twenty properties which one would want an index number formula to satisfy have been suggested, but it is neither desirable nor suitable to go through all of these here¹. Nonetheless, Diewert has shown that the Fisher ideal price index (eq. 5) satisfies no less than 21(!) of the various tests and he has also concluded that it probably is the best when pursuing the axiomatic approach, with, in overall, the Marshall-Edgeworth index (eq. 7) as a worthy competitor.

¹ Some extra tests are as follows:

Laspeyres (1871, pp. 296-314) Proposed *the strong identity test*, which states that if prices in the two periods under consideration remain constant, the level of prices should remain unchanged even if the quantities change. Westergaard (1890, pp. 218-219) proposed the *circularity test*, which states that it shouldn't matter whether one computes the inflation rate between year 0 and year 2 in one or two steps.

Pierson (1896) informally proposed two different tests. The first was *the invariance to changes in the units of measurement test* (which later became known as *the commensurability test*), which states that it should not matter what units the prices (dollars, pounds etc.) and quantities (kilograms, numbers, litres etc.) are used in the computations. The second was *the time reversal test*, which states that the price index should be independent of which period, base or current, one chooses.

The stochastic or statistical approach revisited

Armed with our knowledge of various tests and axioms, we can now apply this reasoning to the indexes developed within the statistical/stochastic test framework. Instead of using the price relatives, as in eq. 10, we can use the logarithm of the price relatives:

$$\ln(p_n^1/p_n^0) = \beta + \varepsilon_n; \quad n = 1, 2, \dots, N \quad (\text{eq. 16})$$

where $\beta = \ln \alpha$ and ε_n are independently distributed random variables as above with mean 0 and variance σ^2 .

The least squares estimator of β is actually the logarithm of the geometric mean of the price relatives. This gives rise to the Jevons price index, P_J (eq. 12).

The (big) problem with this index, however, is that each relative price, p_n^1/p_n^0 , is seen as equally important and is thus given an equal weight in the formula.

In order to get around the problem with unweighted price ratios, enter Theil (1967) and *his* measure of overall logarithmic price change:

$$\ln P_T(p^0, p^1, q^0, q^1) \equiv \sum_{n=1}^N (1/2) (s_n^0 + s_n^1) \ln(p_n^1/p_n^0) \quad (\text{eq. 17})$$

where s_n^0 and s_n^1 are the expenditure shares of commodity n in period 0 and 1 respectively. The construction of the index, which is based on probabilistic reasoning, happens to be equal to an index previously defined by the Finnish economist Törnqvist (1936) and thus goes under the name Theil-Törnqvist index (P_T).

It can be shown that the logarithm of the Theil-Törnqvist index (i.e. as in eq. 17) can be interpreted as the expected value of the distribution of the logarithmic price ratios (*the expected value of a distribution* is here a statistical concept).

In this context it is interesting to look at weighted stochastic approaches where one considers the distribution of price ratios, p_n^1/p_n^0 , rather than the logarithmic ones.

Suppose now that we draw price ratios, p_n^1/p_n^0 , at random in such a way that each dollar of expenditure in period 0 has an equal chance of being picked. The probability that one will draw the n th price ratio is then equal to s_n^0 , the expenditure share of good n during period 0. The overall price change becomes:

$$P(p^0, p^1, q^0, q^1) = \sum_{n=1}^N s_n^0 (p_n^1/p_n^0) \quad (\text{eq. 2})$$

which actually is the Laspeyres price index (eq. 2)! The implication is that the Laspeyres index can be used for studying sampling problems within the stochastic/statistical approach.

In Diewert's opinion, the Theil-Törnqvist index can arguably be seen as the "best" formula when employing the weighted stochastic approach.

The economic approach

A fourth approach to price indexes is radically different from the ones previously described. Let us make it clear from the beginning: developed by economists, this is an approach *not* appreciated by price statisticians:

*“...due perhaps to the overly formalistic presentation of
The theory or the “unrealistic” nature of the assumptions made.
These skeptical price statisticians were much more comfortable
with the fixed basket approach to index number theory...”*

(Diewert 2001, p. 168)

The economic approach is also considerably more mathematical.

The approach is based on consumer and producer theory: economic agents are seen as rational actors. Thus, consumers optimize their behavior by maximizing their utility (or, equivalently, minimizing their expenditures), and producers optimize their behavior by maximizing their profits. For that reason, the economic approach yields not so much a price index, but rather a cost-of-living index; from this perspective, inflation might be seen as the increase in price level consistent with constant utility.

The theory of the cost-of-living index for a single consumer or household was pioneered by the Russian economist Konüs (1926, pp. 16-18). The main difference between the economic and axiomatic approach is that in the economic approach one does not assume that the quantity vectors q^{t+1} and q^t are independent of the price vectors p^{t+1} and p^t . Instead, the period t quantity vector q^t is determined by the the consumer's preference function f , and the period t price vector p^t ; similarly, the quantity vector q^{t+1} in period $t+1$ is determined by the same preference function f and price vector p^{t+1} .

The consumer's cost function C which is generated by f may be defined as:

$$C(u, p) \equiv \min_q \{p \cdot q : f(q) \geq u\} \quad (\text{eq. 18})$$

i.e. $C(u, p)$ is the solution to the problem of minimizing the cost $p \cdot q \equiv \sum_{n=1}^N p_n q_n$ of achieving at least the utility level u , where $p \equiv [p_1, p_2, \dots, p_N]$ is the price vector facing the consumer.

Does this sound familiar? In this context it is worth mentioning that a large portion of revealed preference theory that is often attributed to Hicks (1940) and Samuelson (1947, p. 157) had already been developed by Pigou, Konüs, Haberler and Frisch.

The Konüs family of true-cost-of-living indices for two periods where the consumer faces the price vectors p^t and p^{t+1} for period t and $t+1$ respectively, is defined as the ratio of the minimum costs for achieving the same utility level $u=f(q)$ where q is a reference quantity vector:

$$P_K(p^t, p^{t+1}, q) \equiv C[f(q), p^{t+1}] / C[f(q), p^t] \quad (\text{eq. 19})$$

It is a *family* of price indices because there is one index for every chosen reference vector q . If one chooses the period t quantity vector q^t as reference vector, one ends up with the Laspeyres-Konüs true-cost-of-living index, while if one instead chooses the period $t+1$ quantity vector q^{t+1} as reference vector, one ends up with the Paasche-Konüs true-cost-of-living index².

We are back to a situation similar to the one described above in connection with the fixed basket approach: to make further progress we need to make more specific assumptions, in this case about the functional forms of f or C ³.

We will, however, spare the reader this complexity and simply sum up the results of the economic approach: The Walsh, the Fisher and the Theil-Törnqvist indexes can be regarded as equally desirable from the viewpoint of the economic approach (Diewert 2002, p. 38).

Discussion of the problem areas in constructing a consumer price index

1. Treatment of quality change and new commodities

When employing the fixed-base Laspeyres approach in practice, expenditure shares for *basic commodity classes* are estimated; they are usually in the hundreds. Each such commodity class (could be meat, clothes, furniture *etc.*) consists of a sample of representative items, and these items are priced every month. The prices in the current month are related to the corresponding prices in the base period and long-term relative price relatives are computed. These long-term relative prices are averaged for every commodity class and it is the average relative price for each commodity class that is inserted into the Laspeyres formula (eq. 2). There is a problem with this methodology, however: the ever more rapid rate of disappearance of old and appearance of new goods and services (Diewert 1993, 2001, 2002).

² It can be shown that the unobservable Laspeyres-Konüs true-cost-of-living index is bounded from above by the observable Laspeyres price index, and that the unobservable Paasche-Konüs true-cost-of-living index is bounded from below by the observable Paasche price index (Konüs 1924,1926). Furthermore, it can be shown that the Laspeyres price index has a non-negative substitution bias relative to the corresponding true-cost-of-living index, while the Paasche price index has a non-positive substitution bias relative to the corresponding true-cost-of-living index. This means that the Laspeyres index will generally have an upward bias relative to a cost-of-living index, while the Paasche index will generally have a downward bias relative to a cost-of-living index.

³ It is worth noting that the same type of reasoning as above can be applied to the production side of an economy; after all, the quantities consumed are related to the quantities produced, and the prices paid are related to the prices demanded. Then the problem is turned into one about maximizing the profit functions of firms.

In practice, a substantial fraction of the items in the commodity classes can not be matched exactly for more than a couple of months at a time. In order to adjust for this, one employs a technique called *hedonic regression* (Woolford 1999). We will not go into details here, but be content with a very rough description. The item in question is divided into its constituent “characteristics”, and a value (or price) of each characteristic is computed based on market values. In the case of a mobile phone such characteristics could be the quality of the camera included, number of features, battery quality *etc.* There is, however, a very big cost in doing these hedonic regressions, and there will be some loss of reproducibility and objectivity because the various “operators” of the hedonic regressions will not always end up with the same quality adjustments. Diewert (2002, p. 45) sees no other way of overcoming the problem, however, and claims that after this quality adjustment there is no conceptual problem with applying the fixed-base Laspeyres methodology.

2. Substitution bias or representatives bias

Substitution bias is the difference between a “true” cost-of-living (COL) index and the corresponding Laspeyres or Paasche indexes.

The fixed-base indexes assume that the consumer does not buy less of a commodity that has become more expensive going from one period to another. One could also see it from another perspective: since the quantity weights that are used in the Laspeyres index are representative of only one of the two periods under consideration, they are in general not representative of both periods. One can thus say that the Laspeyres index suffers from *representativity bias* (Diewert 1993, 2001, 2002).

It can be shown (Diewert 2002, pp. 45-48) that the approximate representatives bias, B_L , for the Laspeyres formula is given by

$$B_L(i_1, i_2, \dots, i_N) \equiv (1/2) \sum_{n=1}^N s_n [i_n - i^*]^2 \quad (\text{eq. 20})$$

where i_n is the inflation rate for the n th commodity going from period 0 to period 1, s_n is the expenditure share of commodity n in period 0, and $i^* \equiv \sum_{n=1}^N s_n i_n$

Or, in words, B_L is equal to one half of the variance of the commodity-specific inflation rates between the two periods under consideration. A conclusion is therefore that a Laspeyres type index will generally show higher rates of inflation than a pure price index that uses more representative quantity weights. Since most, if not all, statistical agencies use the Laspeyres methodology this is of minor concern when inflation levels across countries and regions are compared. It does matter, however, when people are compensated for inflation according to cost-of-living indexes: they are typically over-compensated.

3. Fixed-base versus Chain Indexes

When constructing a series of index numbers which extends over three or more periods, one can employ either *the fixed-base principle* or *the chain principle* (Diewert 1993).

We illustrate. Assume that we have price and quantity data for three periods and a bilateral price index function $P(p^1, p^2, q^1, q^2)$, i.e. it depends only on data for two periods. The *fixed-base* sequence of aggregate price levels for the three periods would then be

$$1, P(p^1, p^2, q^1, q^2), P(p^1, p^3, q^1, q^3)$$

The *chain* sequence of aggregate price levels would instead be

$$1, P(p^1, p^2, q^1, q^2), P(p^1, p^2, q^1, q^2) * P(p^2, p^3, q^2, q^3)$$

Historically, the fixed-base principle was the first to be used empirically. The chain principle was first proposed (at least in the English literature) by Alfred Marshall (1887, p. 373) as a method of overcoming a problem described above: the introduction of new commodities. Irving Fisher (1911, p. 204), who coined the term *chain principle*, also saw the advantage of the method in dealing with the introduction of new commodities:

"It may be said the cardinal virtue of the successive base or chain system is the facility it affords for the introduction of new commodities, the dropping out of obsolete commodities, and the continued readjustment of the system of weighting to new commodities."

(Fisher 1911, p. 204)

Importantly, Fisher also noted that the chain system was invariant to changes in the base period. However, it turned out that the chain principle has a severe disadvantage: if the prices and quantities systematically alternate around constant values, the results will be biased. This is referred to as a failure of Walsh's multi-period identity test. It turns out, however, that both the chain and fixed-base systems fail not only this test, but also other identity tests which might be considered appropriate from a theoretical perspective. In order to resolve this problem, possible alternatives to the use of either the fixed-base or chain systems were proposed.

The problem with multi-period systems of index numbers, however, is that not enough research has been done on the axiomatic properties of the various alternatives, and this makes it difficult to endorse any of them.

There is another interesting imperfection with constructing a series of index numbers extending over three or more periods: how often one changes the base year has an impact on the Laspeyres (and Paasche) price index. Assuming that the expenditure shares, s_n , for each commodity n remain constant from period to period, it can be shown (Diewert 2002) that if the long-term price relatives $p_n^t/p_n^0 \equiv 1 + i_n^t$ increase (or decrease) *linearly* with time t , then the approximate representativity bias for the period t Laspeyres fixed-base formula will grow *quadratically* with time. However, under the same assumptions, the *chained* Laspeyres (and Paasche) price indexes will diverge at a rate that is only linear in time. On the other hand, if the long-term price relatives p_n^t/p_n^0 do not grow linearly with time, but simply fluctuate around a constant, then the previously mentioned conclusion will not hold, and both the fixed-base and chained Laspeyres price indexes will exhibit much the same behavior. The implication for statistical agencies around the world is pretty clear: each country should compute the variance of their long-term price relatives and determine whether these variances are growing at faster rates than the long-term price relatives themselves. If this would be the case, then the frequency of rebasing will make a difference to the aggregate country index.

The conclusion from this is that in order to make country inflation rates comparable, the frequency of rebasing must be the same in all countries. The construction of series of index numbers is rather complex, however, involving computations on several levels. We will not go into further details thereof in this paper.

4. The choice of formula at the elementary level

We start with a repetition of the construction of the Laspeyres price index, as it works in practice, to make clear what constitutes the elementary level (see also section 1, *Treatment of quality change and new commodities*, above). Expenditure shares for about a couple of hundred product groups (e.g. rice, pasta, beef, pork *etc.*) are estimated. Each such product group consists of a sample of representative items, and these items are priced every month.

The prices in the current month are related to the corresponding prices in the base period, and long-term relative price relatives are computed. These long-term relative prices are averaged for every product group and it is the average relative price for each product group which is inserted into the Laspeyres formula. The question now is: exactly how should the sampled long-term price relatives *within* the product groups, i.e. at the elementary level, be averaged before they are inserted into the Laspeyres formula? Diewert (1993, p. 49) examines three different types of averaging which could come into question: the Dutot index, the Jevons index, and the Carli index⁴. But why cannot the Laspeyres price index be used on the elementary level as well? One reason is that individual consumers may purchase the same item during period t at different prices; another is that a particular shop or outlet that sells to consumers may very well sell at very different prices during the course of the period. We have what we may call a non-trivial first stage aggregation problem⁵.

⁴ The Dutot and the Carli indexes, P_D and P_C respectively, have not been presented before in this paper. If there are K prices in the sample of prices for the commodity class, the Dutot formula is defined as:

$$P_D(p^0, p^1) \equiv (1/K) \sum_{k=1}^K p_k^1 / (1/K) \sum_{k=1}^K p_k^0 = \sum_{k=1}^K p_k^1 / \sum_{k=1}^K p_k^0 \quad (\text{eq. 21})$$

The Carli index is defined as:

$$P_C(p^0, p^1) \equiv \sum_{n=1}^N (1/N) (p_n^1 / p_n^0) \quad (\text{eq. 22})$$

The formula for the Jevons index has been given above (eq. 12) but is repeated here for convenience:

$$P_J(p^0, p^1) \equiv \prod_{n=1}^N (p_n^1 / p_n^0)^{1/N} \quad (\text{eq. 12})$$

Is the use of these formulae consistent with the overall Laspeyres index methodology? Diewert (2002, p. 49) asked this question and argues - the discussion is highly technical - that provided "appropriate sampling schemes" are undertaken the Dutot index and, as it happens, the Carli index, can be justified as approximations to an underlying Laspeyres price index for the commodity class under consideration. The Jevons price index, however, cannot (but, as we shall see, is used nonetheless).

⁵ Diewert's analysis has its basis in an aggregation procedure where the quantity of a narrowly defined good is the total quantity of the good sold during the period, and the price of the good is the total value of the good sold divided by the total quantity.

Diewert suggests some other indexes which come out with better properties in his analysis, but, more interestingly, finishes off with high hopes that ever more detailed scanner data from shops and outlets will be very useful for constructing indexes at the elementary level. This might be very welcome: Diewert (2002, p. 54) points out various studies which have shown that the biases are considerably higher than previous ballpark estimates. In fact, the measures of price change based on scanner data are often considerably *below* the corresponding official measures. This is highly relevant from a Swedish inflation measurement perspective.

As we shall see later in this paper, Sweden is at the forefront when it comes to collecting data via the shops' cash registers.

5. The treatment of housing

When a consumer buys a durable good (other than housing), national CPIs (and the HICP, the index used by the ECB, see below) attribute all of the expenditure to the period of purchase, even though it is possible to take advantage of the services of the good also in future periods. The treatment of owner-occupied housing in different national CPIs, however, is more diverse (Diewert 2005, p. 55).

There are four different approaches to accounting for housing services in a CPI. One is *the rental equivalence approach*, which estimates a price for using the owner-occupied dwelling that is equal to the price of renting an equivalent place to live. It is an opportunity cost approach: the owner values the services yielded by his or her dwelling by the amount of rental income it could generate during each period⁶.

⁶ The approach is used by the Bureau of Labour Statistics in the U.S. According to Diewert (2002, p. 58), the approach can fail under two conditions. The first is if the rental markets for some classes of owner-occupied housing is very thin or outright non-existent. The second is if the rental markets are unrepresentative, e.g. if expensive houses are rented to friends or relatives at reduced rates in exchange for services. If any of these two conditions are relevant the rental equivalence approach will fail and an alternative approach must then be used: *the user cost approach*.

Statistics Iceland uses *the user cost approach*. The problem with this approach is that the services emanating from the purchased goods are not confined to period 0: the purchase will also yield a *flow* of services to the consumer in future periods. The question, then, is how to allocate the purchase price across periods⁷.

The net acquisitions approach is actually identical to the treatment of purchases of other consumer durables. In practice this means that the quality-adjusted price of new houses in the current period is compared to the price of new houses in the base period; the weights in the index are the net purchases of new houses by the household sector in the base period⁸.

The payments approach measures actual cash flows: on down payments, mortgage repayments and mortgage interest, or some subset thereof. The approach always includes mortgage interest payments, however. It can thus be seen as a kind of cash flow approach to the costs of operating an owner-occupied dwelling⁹. The payments approach generally leads to much smaller monthly expenditures on owner-occupied dwellings than the other approaches. It was used in the U.K. until 1994 and is still used in Ireland.

⁷ As it happens, this is the fundamental problem of accounting. The costs can be allocated in numerous ways. The simplest is probably to employ *historical cost accounting*: the cost is allocated over the periods the good is yielding services, either evenly or taking actual depreciation into account. Another way is cost allocation based on opportunity costs. The purchase of the good is viewed more as an investment, and in this case one has to take into account not only depreciation rates, but also nominal interest rates and inflation rates. The analysis is highly technical, so here we will be content with presenting only the differences emanating from the different approaches (below). For the reader interested in the details we refer to Diewert (2002, pp. 58-64). Let us mention, however, some of the problems which might arise when implementing a user cost approach to housing: 1) it is difficult to determine what the nominal interest rate is for each household, 2) it is difficult to determine the relevant depreciation rate for housing, 3) the user cost of housing is made up of the user cost of structures as well as the user cost of land, 4) various taxes associated with housing must somehow be accounted for, 5) the treatment of renovation expenditures.

⁸ It is worth noting that the price does not include the land that the dwelling sits on. A few countries, e.g. Australia and New Zealand, have used this approach. The problem with the approach is that purchases of new houses do not all reflect the actual consumption of housing services for the population of owner-occupiers. That means that if the purpose is to measure the real consumption of the population during a period, and a price index is required to deflate nominal consumption expenditures into real consumption, then the acquisitions approach to the treatment of owner-occupied housing will be unsatisfactory (Diewert 2002, p. 57). It can be shown (Diewert 2002, p. 62) that an acquisitions approach to housing in the CPI is likely to give about half the expenditure weight that a user cost approach would give. For assets with a shorter life-span the difference between the two approaches will be modest and the use of the acquisitions approach can be justified as being approximately correct as a measure of consumption services.

⁹ Diewert (2002, p. 56) points out that the approach ignores the opportunity costs of holding the equity in the owner-occupied dwelling and that it also ignores appreciation. He admits, however, that adjusting for the imputed costs would lead to a rather complicated user cost approach. In summary, the payments approach is not very suitable as a measure of general housing inflation.

As we shall see later, the European Central Bank (ECB) completely omits the treatment of owner-occupied housing in its Harmonized Index of Consumer Prices (HICP).

To sum up, there are various methods to treat costs for housing in a CPI. Naturally, this makes it less easy to compare inflation levels across countries. The exact consequences thereof are beyond the scope of this text.

6. The treatment of seasonal commodities

The consumption of some commodities varies significantly and systematically with the time of the year; some commodities are even impossible to find during long periods of the year. The problem is not slight: seasonal commodities comprise 20 to 30 percent of the commodities in a typical CPI (Diewert 2002, p. 64).

How is it at all possible to compare the price of a commodity in a month to a price in a previous month during which it was not at all available? Furthermore, even though a commodity might be available during all months of a year, the amounts consumed might vary a lot depending on month. This causes problems with the CPI because the base period expenditure weights are usually average expenditures during that base year.

Mudgett (1955, pp. 93-98) and Stone (1956) have proposed a theoretical solution to the problem. Each commodity n (of N in total) in each month is seen as a separate commodity and normal index number methodology is employed to compare 12 months of price data for the current year with the corresponding 12 months of price data for the base year. In all, $12N$ prices for the current year are compared with $12N$ prices in the base year¹⁰.

The Harmonized Index of Consumer Prices (HICP)

After reviewing the early history of consumer price indexes and the theory behind their construction, time is now ripe to take a step further toward reality: to sort out how all these theo-

¹⁰ The adjustment can be made ever more refined with the collection of more price data (Diewert 2002, pp. 64-67). In reality, however, the adjustment process can be somewhat opaque to an outsider: The Bureau of Labour Statistics, for example, refers to the use of "X-13ARIMA-SEATS (auto-regressive integrated moving average) seasonal adjustment software". Furthermore, "X-13ARIMA-SEATS uses the X-11 seasonal adjustment method in conjunction with regression-ARIMA modelling for intervention analysis and data extension" (Bureau of Labour Statistics 2015). The X-13ARIMA-SEATS software was developed by the U.S. Bureau of the Census in 2013.

ries and ideas are translated into practice (Diewert 2001, 2002).

We start with looking at the Harmonized Index of Consumer Prices (HICP), which is the inflation measure used by the European Central Bank (ECB), the central bank of the European Monetary Union (EMU).

We think it is appropriate to use the HICP as a starting point for a discussion of real-life measurements of inflation because it is a price index which has very recently been designed from scratch, and the discussion about its construction has been amply documented. In most respects, however, it is of course very similar to other CPIs used all over the world.

It is fair to say that the monetary policy of the ECB is modelled on the monetary policy of Bundesbank, the former central bank of Germany. When the Berlin Wall came down in 1989 it did not take long until the question of (re)unification of West and East Germany came to the fore. Both Britain and France were hesitant, fearful of a once again strong Germany in the center of Europe not even 50 years after the defeat of the vicious Nazi regime. An agreement was finally reached whereby unification was accepted provided that Germany committed itself to the creation of a common European currency. The Bundesbank, with its strong focus on low inflation through strict control over the monetary supply, enjoyed strong domestic popular support, and the Germans were adamant that the monetary policy of the future ECB should be conducted in the same vein. Therefore, it was decided early on to view inflation as essentially a monetary inflation.

The euro was introduced as currency within the Eurozone on January 1 1999 and at the same time the ECB started to exercise its full powers. The basic tasks of the ECB are to define and implement the monetary policy for the Eurozone; to conduct foreign exchange operations and thus to take care of the foreign reserves of the European System of Central Banks; and to promote the smooth functioning of the financial market infrastructure under the TARGET2 payments system. The main, and only, primary objective of the ECB is to maintain price stability within the Eurozone. Price stability has been defined as “a year-on-year increase in the Harmonized Index of Consumer Prices (HICP) for the euro area of below 2%” and it “was to be maintained over the medium term”. The principle of the price stability objective has been formally laid down in “The Treaty on the Functioning of the European Union”, while the explicit number target has been decided on by The Governing Council of the ECB.

It has later been clarified by the same Council that “in the pursuit of price stability, it aims to maintain inflation rates below, but close to, 2% over the medium term”; it is worth pointing out that the target is not defined in statutory law. We see here another important reason for measuring inflation: a central bank having inflation targeting as its monetary policy must somehow measure inflation. An important question which we have not covered so far is defining what prices and quantities to include in a price index. Or, more formally, what set of transactions in an economy under consideration should be in *the domain of definition* of the target index?

Early "inflation" theories for the price index specified that the set of transactions that the price index should encompass is the set of all monetary transactions that occurred in the economy in the two periods being compared. Irving Fisher (1911) stated that the formation of such a general index number must include all goods and services. Moreover,

"... how much weight should be given, in forming the index, to the stock of durable capital and how much weight to the flow of goods and services through a period of time, the flow to individuals, which mirrors consumption? Shall we count the railways of the country as equally important with a month's consumption of sugar, or with a year's?"

(Fisher 1911, p. 201)

He referred to his equation of exchange, $MV = PY$, and wrote

"by this means, goods bought for immediate consumption are included in the weighting, as are also all durable capital goods exchanged during the period covered by the index number. What is repaid in contracts so measured is the same general purchasing power. This includes purchasing power over everything purchased and purchasable, including real estate, securities, labor, other services, such as the services rendered by corporations, and commodities".

(Fisher 1911, pp. 217-218)

To include all and every transaction is impossible in the modern world: the transactions in the currency and stock markets are huge and would alone completely flood the more interesting transactions.

Thus, the domain of definition must somehow be reduced. But how? Exclude seasonal goods? Exclude consumer durables? Include future goods or savings? Include leisure? Include commodity taxes? Exclude commodities with highly variable prices? The ECB and its monetary policy replaced the monetary policies of all the central banks of the different countries that joined the Eurozone. To accommodate all these diverse interests might be hard enough, but complicating matters further were the rather different economic conditions in the prospective member states. For example, at the time of the introduction of the HICP about 85 % of Spaniards lived in owner-occupied dwellings, while only 40 % of Germans did so; leaving out imputed rents (see below for an explanation) from the domain of definition of the index would thus lead to inconsistent comparisons between Spanish and German inflation rates (Diewert 2002, p. 9).

The architects behind the HICP presented the main features of the HICP in two papers (Astin 1999; Berglund 2000). We will go through the most noteworthy among them.

- a) It should only encompass market transactions, i.e. imputations such as user costs or imputed rental prices for owner-occupied housing would not be included (with imputation is meant the assignment of value to something by inference from the value of the products or processes to which it contributes, (Oxforddictionaries 2016).
- b) It should not include interest rates or interest costs since "such costs are neither a good nor a service, but the instrument for balancing the supply and demand of money" (Berglund 2000, p. 69). The architects admitted that in the context of a compensation index, interest payments constitute a relevant part of the expenditure of households and is therefore reasonable to include, but argued that *when it comes to an inflation index* they are not (Astin 1999, p. 5).
- c) The index should treat owner-occupied housing in one of two ways. Either one excludes owner-occupied housing from the index or includes only new purchases of dwelling units, essentially treating purchases of dwelling units like any other purchase of a consumer durable. At present, the HICP excludes both the services of owner-occupied dwellings and purchases of new dwellings.

The architects of the HICP saw the imputed-rents method as a valuable concept in the context of the measurement of the volume of consumption of housing services, but as irrelevant in the context of the measurement of *price change*.

In a cost-of-living approach to the CPI, however, the consumption of owner-occupied housing would be valued according to the rental equivalence approach or to the user-cost approach¹¹. When it comes to interest payments and CPIs few economists would accept the argument that interest is the cost of borrowed money and hence is neither a good nor a service. On the contrary, they would regard it as a payment for the use of financial capital for a specified period of time, and hence regard it as a service. Thus, interest is a price just like any other price: it is the price a borrower must pay to the lender for the use of financial capital during a specified time period¹².

- d) The harmonized index should use the Laspeyres formula, but the basket must be updated between one and seven years with a preference for more frequent reweighting; the Laspeyres formula was deemed to be more practical than the Paasche.
- e) Consumer prices rather than producer prices should be used in the HICP.
- f) The prices of highly subsidized consumer goods and services should be the prices faced by the consumer.

¹¹ Note that the HICP aims at measuring inflation, and *not* as working as a cost-of-living index. In the rental equivalence approach, the consumption of owner-occupied home would be valued at a comparable market rental price; this price must necessarily be an imputed (estimated) one. In the user-cost approach to the purchase of a consumer durable, it is explicitly recognized that not all of the good is consumed in the period of purchase. The purchase, according to this view, should be divided into two parts. The first part is the cost to the consumer of using the services of the commodity during the period of purchase. The second part is a form of investment that will yield either a return or services to the consumer in future periods. According to Diewert (2002), the user-cost approach would provide a way to value the services of the older vintages of household consumer durable goods, and thus allow for building up a more comprehensive picture of actual household consumption compared to an approach where only new purchases are included.

¹² Woolford (1999), however, has suggested an interesting reason for the possible exclusion of interest rate from a price index: interest is not a *contemporaneous price*. He argues that an interest rate necessarily refers to *two* points in time, a beginning point when the capital is lent/borrowed and an end point when the capital must be paid back. Thus, if for some reason, one wanted to restrict attention to a domain of definition that consisted only of contemporaneous prices, interest rates should be excluded. However, interest rates *are* prices, although they are more complex than contemporaneous prices.

The properties **a)-f)** (and some other properties not mentioned here) make it possible to distinguish the index from a cost-of-living (COL) index based on consumer theory, or a producer-price index (PPI) based on producer theory¹³.

Diewert (2002) criticizes the "theory" (his citation marks) of the HICP on the grounds that it seems to lack an underlying firm theoretical basis. He acknowledges that the purpose of the HICP is as a measure of inflation that is based on actual transactions that use money, but argues that a measure of inflation based on "monetary" transactions is too broad to be useful¹⁴. It can be mentioned that the economic approach, which Diewert advocates, is met with a high degree of skepticism among price statisticians (see above).

The Swedish Consumer Price Index (KPI)

The Swedish CPI (henceforth denoted KPI) is computed by Statistics Sweden (SCB), an assignment given to them by Riksbanken (the Swedish Central Bank), in order to help Riksbanken to make qualified decisions about the actions needed to reach the targeted inflation rate of 2 percent. We will come back to the interest of a central bank in inflation measurements in a later section. Other institutions which use the KPI for operational purposes include:

- The ministry of finance in order to make projections about economic cycles and maneuver governmental policy
- The ministry of social health and affairs in order to adjust welfare benefits and student loans for inflation
- The Swedish tax agency in order to adjust the income levels at which the tax rate starts

¹³ It should be acknowledged, however, that it is difficult to define (and implement) either a cost-of-living index or a producer-price index that covers consumer expenditures in a consistent way. The problem with COL is that households engage in household production which makes it difficult to determine whether a household purchase is an intermediate input or a final demand purchase. Similarly, the problem with the construction of a PPI is that some (unknown or difficult-to-determine) fraction of business sales of consumer commodities is actually to other business units which use them as intermediate inputs.

¹⁴ Instead, he is a proponent of a dual approach to index number theory, based on the two classes of consumption price indexes that emerge from the national accounts (and economic theory), and which he claims would fill out the boxes in the *System of National Accounts: 1993*, where there are *basic prices* (corresponding roughly to producer prices; producer theory approach) and *final demand prices* (which correspond to consumer prices in the case of the household components of final demand; consumer theory approach). Nonetheless, he admits that it is difficult to construct a completely consistent index of consumer prices no matter what methodology one uses as the starting point.

or increases

The KPI is produced to measure the average increase of consumer prices, and thus give an indication of how the inflation rate is progressing. SCB uses 1980 as base year (1980 = 100), and calculates the KPI as a 12-month change in prices, with a plus one-month change (12+1) time series that accounts for miscalculations during previous months. The period during which data is gathered is usually from December to December the following year, and this constitutes a one-year chain. Thus, the KPI is a cost-of-living index derived from the *chain index principle* with its advantages and disadvantages as discussed earlier in this paper. All goods and services that are available for purchase within the nation is an object for analysis. Thus, international consumption by Swedes abroad is not included in the Swedish KPI. However, charter and other package trips bought from Swedish retailers are accounted for, even if the majority of service is utilized internationally (Statistics Sweden 2015).

All products available to the public are classified according the *Classification of Individual Consumption According to Purpose* (COICOP), as belonging to a specific product group (United Nations Statistics Division 2016). Assigned to every group is a weighting that is equivalent to the value of the market share of that group, and since the selection of products are selected via proportional selection probabilities given the level of consumption, the selection of products becomes self-weighted (Statistics Sweden 2015, p. 21).

Once the products determined to be included in the analysis have been specified, the stores to be included in the survey are selected. In order to eliminate selection bias, the selection is undertaken with a Poisson selection process. This guarantees that the selection-probabilities are in proportion to the size of the market share of the stores. SCB uses yearly rotation that affect about 20% of the stores (Ohlsson 1990).

The gathering of prices occurs monthly, one week before, and one week after the 15th. However, the prices of some products with shorter lifespan, e.g. computers and smartphones, are measured continuously over the month. The price registered is the final price the customer has to pay, including sales taxes, without being obligated to any services in return. The majority of data from commodity goods are gathered via the shops' cash-registers, where all transactions have an EAN-code. The code contains all pertinent information about the individual transaction: product, price store *etc.* There are about 700 products per store reported through the use of an EAN-code every month, an estimated world record in the world of CPI-statistics

(Statistics Sweden 2015).

In cases where EAN-code reporting is not possible, other means of obtaining price information are employed. For example, landlords and other real estate owners are interviewed about housing prices and rents via standardized questionnaires that are sent to the respondents. When conducting interviews, the interviewer uses a small handheld computer that has all information about the specific respondents.

The real-life computation of the KPI is fairly complex, and we will not go into any details in this paper, but be content with a rough overview. On the elementary level (product group) a Jevons index is employed (Statistics Sweden 2015, p. 43-49). However, no index fits all purposes. Regarding products and services in non-competitive sectors, such as sanitation or sewerage. that are provided by the government, the Laspeyres index is the preferred index of choice. Finally, aggregation of the product groups to higher levels, COICOP groups and the final KPI, is made with a Laspeyres index, and to some extent, with a Walsh index.

Products with short durability due to rapid technical progress (e.g. mobile phones, computers), whose prices are measured continuously over the month, are treated somewhat differently. The method of hedonic regression (see above) is then employed (Statistics Sweden 2015, p. 43-49).

Dwelling costs

In contrast to the countries within the Eurozone, Sweden (and most countries in the world) takes dwelling costs into account when computing the KPI. The total index used for calculating costs originating from housing is a weighted average of several sub-indexes (Haglund 1999). Some of these sub-indexes take into account recurrent costs such as costs for drain, water and overall maintenance, while others take into account capital-related costs such as interest and mortgage payments. One sub-index that is particularly interesting in the context of this paper is the index for interest rate costs (R).

The index is composed of two factors which themselves are indexes, in some sense these can be viewed as "sub-sub-indexes" (eq. 23):

$$R_0^m = 100 * RS_0^m * KS_0^m \quad (\text{eq. 23})$$

where RS_0^m is an interest rate index (RS) and KS_0^m is a capital stock index.

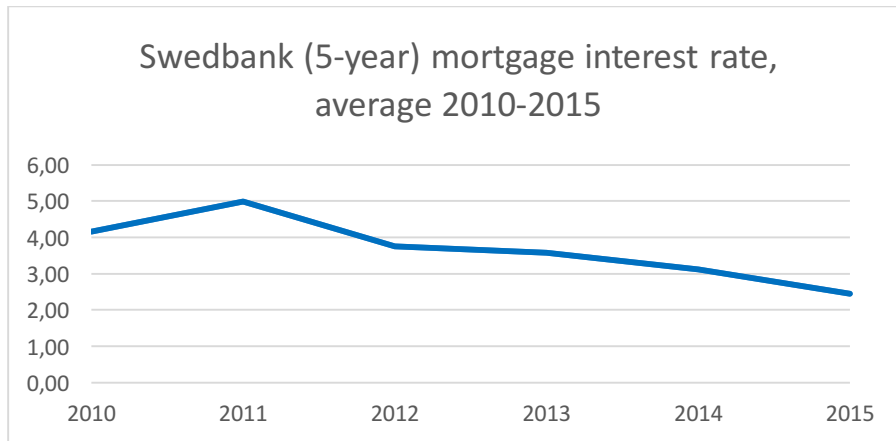
The interest rate index seeks to explain the average change of the interest rate that borrowers, i.e. households, face when applying for a mortgage. The capital stock index seeks to explain the change in price over time for comparable houses with the same purchase price; in other words, it is a measurement of the change in the value of the capital to which the interest rate costs are attributed¹⁵.

The equation will not be discussed in depth, but we will just mention that it is used to measure to what extent households pay for interest rates compared to the year before. The weighting of the index for interest rate costs (R_0^m) in the overall KPI is not computed with respect to market share, instead it is estimated with the use of a model. Rather than just using the value of housing given in the national accounts, this model attempts to take into account other external factors which might influence house prices, and thereby compute the actual purchase price of all housing in the capital stock. In other words, this is a model which is used to account for other factors that can affect the purchase price of housing – for example, average interest rates for mortgages, number of turnovers, and an estimated constant capital reduction rate – other than just using the value of housing given in the national accounts (Statistics Sweden 2015, p. 27). This means that the variation in the amount of purchased and sold housing between years directly affects the KPI. During a year of frequent turnovers in the housing market, the KPI tends to be higher than during a year of low turnovers. Since a few years, the turnover is decreasing (Hemnet 2016), implying a suppressive effect on KPI. This could thus go some way towards explaining why KPI is currently in the low.

Then, of course, there are the factors of steadily increasing property prices and decreasing interest rates. Since the beginning of 2014, the Swedish central bank has lowered the repo rate in the hope of generating a higher rate of inflation, and the market interest rates have duly followed (figure 1), Swedbank is one of Sweden's largest banks.

¹⁵ In some sense this can be viewed as the change of square meter per fixed krona between different years.

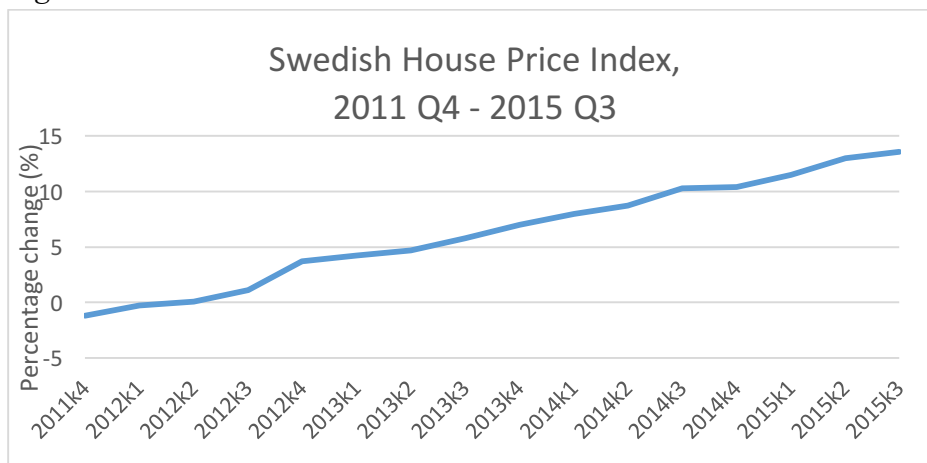
Figure 1



Source: (Swedbank 2016)

The Swedish housing market today suffers from a shortage on the supply side, and the combination with ever lower interest rates has resulted in booming property prices (figure 2).

Figure 2

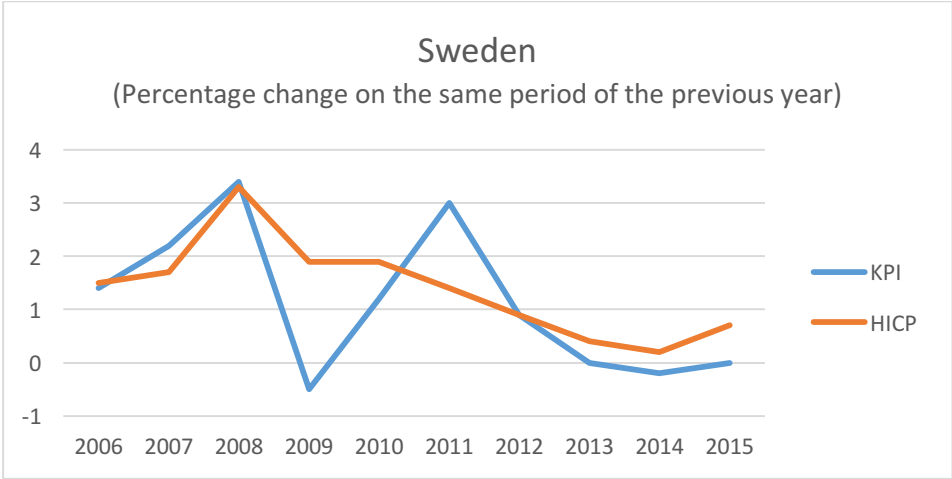


Source: (Statistics Sweden 2016)

Since price changes in the housing market are accounted for in the Swedish KPI (eq. 23), increases in house price should, *ceteris paribus*, put an upward pressure on the KPI (via KS). However, decreasing interest rates should conversely lead to a downward pressure on the KPI (via RS). There is an easy way to find out the net effect of increasing property prices and decreasing interest rates on KPI: a comparison with HICP, which does not take housing costs into account; as a member of the European Monetary Union (EMU), Sweden is obliged to compute and report HICP. As we can see in (figure 3), the HICP for Sweden, in contrast to the KPI, has been consistently positive throughout the period.

It thus seems as if the effect of decreasing interest rates on the KPI more than off-sets the effect on KPI of the increasing house prices, although this analysis does not correct for the rate of turnover on the property market (see above).

Figure 3

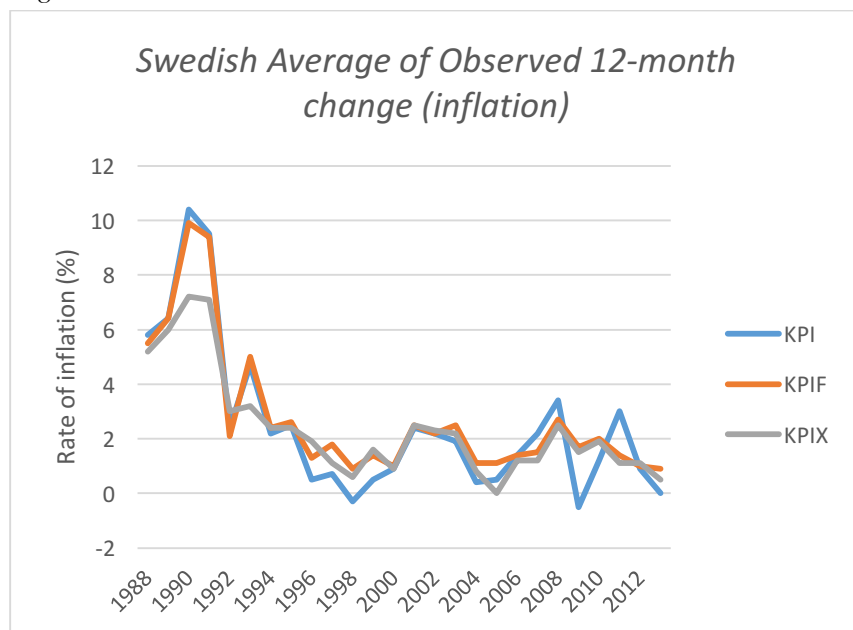


Source: (OECD 2016)

The Riksbank also uses other indexes. One such index is the KPI with fixed interest rates (KPIF). The KPIF measures the underlying inflation where the interest costs for mortgages are excluded. However, the change in capital stock (KS) mentioned before is not fixed, but allowed to differ between years. This implies that the value of KPIF will depend on the current governmental fiscal policy in effect at the time. For example, one policy that could influence the KPIF is the degree of down payment one must make in order to be able to purchase a property.

Another index that tries to deal with the issue of a fluctuating KPI as a result of a volatile housing market is the KPI with the overall interest costs index (R) excluded, the KPIX. This index is also a measurement of underlying inflation and is according to Haglund (1999) a better estimate of the actual price change in the economy because the appreciation or depreciation of capital is excluded from the index and thus a better measurement of the change in value of the actual transactions within a year. (Figure 4) illustrates an average 12-month change between the discussed indexes.

Figure. 4



Source: (Statistics Sweden 2014)

When comparing the KPI, KPIF and KPIX, we observed that KPI expressed the biggest fluctuation around its trend, whereas KPIX varied the least. Thus, one could come to the conclusion that KPIX is a better index for projections about inflation in the more distant future (the long run), while KPI gives a better estimation of the present situation (the short run) since KPIX would underestimate a boom and overestimate a recession.

Discussion and conclusions

Ever since the financial crisis of 2007-2009, the world economic climate has been characterized by, amongst other things, low inflation rates. In fact, during periods negative inflation rates, deflation, have been observed. Since *The Great Depression*, low inflation rates and deflation have widely been seen as symptoms of low economic activity, if not outright depression. Indeed, in many countries economic output has been meagre at best since 2007, and in some countries economic growth has been negative.

Sweden has not escaped the clutches of low inflation; indeed, during the last years the Swedish Central Bank has vigorously battled deflation and has gone to some extremes in order to reach its inflation target of 2 %.

However, judging by most other economic indicators, the Swedish economy looks quite healthy with growth rates exceeding those seen in most other Western economies. This apparent paradox, essentially zero inflation and high economic growth roused our interest in how inflation is actually measured. Furthermore, the housing market in Sweden is buoyant to say the least, and it was somewhat of a mystery to us why that was not expressed in the official inflation figures.

It must be said, however, that there are other factors affecting the inflation rate that currently are out of the ordinary. For example, the oil price is at an almost historic low; the interest rates are exceptionally low, making payments on housing mortgage loans cheaper than ever before (although it helps to fuel the soaring property prices); and the fact that our closest trading partners are also experiencing low inflation rates should not help. Moreover, the Internet, via increased price transparency, is promoting ever fiercer competition, helping to keep the consumer prices down. However, these are factors which Sweden has in common with most other countries, and should therefore be unable to explain the unique Swedish situation: high economic growth concurrent with low inflation. For these reasons, we decided to have a closer look at how inflation is measured in order to see if we could find an answer to the Swedish conundrum.

We found that:

- The term inflation has had different meanings throughout history. It was Keynes who, by redefinition of the concept, made it synonymous with price increases. Thus, the established way to measure inflation is by computing consumer price indexes.
- Consumer price indexes have their origin in the 18th century, and the reason as to why they should be implemented is still valid: they should serve as basis for the computation of compensation for increased costs of living due to rising prices. Thus, the measurement of inflation is important for adjusting welfare benefits and student loans; for wage and rent negotiations aiming at multi-year agreements; for adjustments of income tax brackets; and for various other long-term contracts.
- In modern times inflation measurement has become even more important since the introduction of inflation targeting as a tool for monetary policy.

- There are various approaches to computing consumer price indexes, but the fixed-basket approach is by far the most common. The Laspeyres index is the most common type of consumer price index. The value of a representative consumer basket selected at t is determined at time $t+1$ as well as at the original time t ; the relative value is the Laspeyres index.
- At the elementary level (product groups; e.g. wheat bread, rye bread *etc.*) Jevon's, Carli or Dutot indexes can be used, but when aggregating the product groups to COICOP groups (e.g. the lower level bread or the higher level food) and the CPI the Laspeyres index is used.
- Inflation is not measured in the same way in every country. Notably, in the Eurozone countries costs for owner-occupied housing is excluded from the HICP, the consumer price index of the ECB. Sweden, as a member of the EMU, is obliged to also report inflation as measured by the HICP, and by that figure the Swedish inflation rate is actually higher. Thus, one could say that including costs for owner-occupied housing currently leads to an underestimation of the Swedish inflation rate as compared to those of the countries of the Eurozone.
- The Swedish sub-index for owner-occupied housing is composed of two parts: one accounting for changes in interest rates, and one accounting for changes in property prices. Not surprisingly, the first component of the index currently has a negative effect on inflation, while the second component has a positive effect. The first effect is larger than the second, however, currently leading to a net negative effect on the inflation rate.
- Interestingly, the turnover on the property market also has an impact on the index: in years of high turnover the KPI tends to be higher than in years of low turnover. Since a few years, the turnover has been decreasing, implying a currently suppressive effect on the KPI.
- Sweden has an informal world record in collecting purchasing data from cash register terminals, and research has shown that this leads to lower reported inflation rates as compared with a traditional way of collecting data.

In the light of the findings above, we have come to the conclusion that the inflation in Sweden has been so low despite an economic activity which is generally higher than that in our trading partners. Some of these differences can be explained by the different way of measuring inflation, the inclusion or exclusion of different significant products and goods, or what type of index-method is employed. All in all, there is often more to dissimilarities in different countries CPI's than one first might expect.

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