STOCKHOLM SCHOOL OF ECONOMICS
Master Thesis in International Economics
Fall 2010

Revisiting the exchange rate pass-through to Swedish import prices

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Abstract

In terms of how import prices react to changes in the exchange rate, theoretical arguments have been made that small open economies should be price takers on the international market and thus experience a full pass-through rate. Empirical studies on Sweden and other countries have however refuted this. Given a number of interesting macroeconomic events during the last ten years, my purpose in this thesis is to examine the exchange rate pass-through to Swedish import prices, using monthly data from 1990 to 2009. With the Engle-Granger two step procedure, I examine the relationship between weighted aggregate samples of import prices, home market prices, the exchange rate, domestic economic activity and foreign producer prices. However, no cointegrating relationship is found between the variables with this method and for the time period in question, making a meaningful pass-through estimation impossible.

***Key words**: Exchange rate, pass-through, Engle-Granger, Swedish import prices*

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Presentation*:* 27 September 2010
Location*:* Stockholm School of Economics, Room 328
Time*:* 10.15-12.00

I would like to thank my tutor Richard Friberg, as well as Rickard Sandberg, for their input and advice.

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1 Introduction

The extent to which prices of imported goods react to changes in exchange rates has interested economists in for a few decades by now. Theories that treat prices of equal goods on different geographical markets, such as the law of one price, have earlier ruled out the possibility of price discrimination. If arbitrage opportunities prohibit differing price settings between geographical regions, this should also mean that companies who export goods to foreign markets should keep their prices constant in their own currency, and let the destination market price depend on the exchange rate. This would mean that a change in the exchange rate between the exporting country and the destination market *passes through* in full proportion to the import price, which has given rise to the expression *exchange rate pass-through*.

In reality, however, it has been shown that the law of one price is often refuted. As opposed to the case of homogenous commodities being traded on the world market, many goods markets are differentiated and contain destination-specific features, which enable price discrimination without arbitrage opportunities. This also means that exporters can vary their prices in their own currency to keep destination market prices on a level that is optimal for its specific conditions, such as the level of demand, the elasticity of demand and the competition level.

Earlier theories have assumed that small open economies like Sweden are price takers on the international market and experience import prices that vary in full extent with the exchange rate. Empirical studies, however, have refuted this theory, showing an incomplete exchange rate pass-through for small economies in several studies.

A number of factors that could affect the exchange rate pass-through for Sweden have occurred in the last two decades; many of the country's largest trading partners have now converted their currencies to the euro, the Swedish inflation is historically low and stable and the macroeconomic environment has experienced large fluctuations in terms of economic activity. I will therefore look at data spanning over the last two decades and examine whether pricing to market is present for aggregate Swedish imports throughout the period 1990-2009. Furthermore, I will test if the law of one price holds between Sweden and its largest trading partners and eventually calculate an estimate of the pass-through rate. These tests and the estimation are carried out by examining possible cointegration relationships, or long run

equilibriums, between Swedish import and home market prices, the demand conditions on the Swedish market, foreign producer prices and the exchange rate, using the Engle-Granger two step procedure. This method will test the relationships between the variables based on an established theoretical model that has been commonly used in previous work on the exchange rate pass-through.

The structure of the paper is as follows: Chapter 2 reviews the theoretical background about exchange rate pass-through and related terminology, followed by a summary of previous empirical findings on the subject and finally my approach and motivation for studying the subject. Chapter 3 treats the method of cointegration analysis. Chapter 4 reviews the theoretical model used in the analysis. Chapter 5 describes the data in this study. Chapter 6 summarizes the empirical results and Chapter 7 presents the conclusions.

2 Literature review

2.1 Theoretical background

The law of one price

According to the law of one price, the price of a traded good must be the same on all geographical markets, when expressed in a common currency;

(1) $$P_i = E \times P_i^*$$

E denotes the nominal exchange rate in units of domestic currency per unit of foreign currency, P_i the price of good i on the domestic market in terms of domestic currency, and P_i* the price on the foreign market in terms of foreign currency. In a world economy with perfect competition, costless transport of goods between countries and no trade barriers, this relationship must hold. Otherwise, arbitrage opportunities would arise. An implication of this theory is that price levels change when the nominal exchange rate changes, and the other way around. If we assume an initial equilibrium situation as described above, followed by a value increase of the domestic currency, so that $P_i > E \times P_i^*$, foreign goods will become cheaper

and be preferred by consumers. The decreased demand for domestic goods will result in a decrease in the domestic price (P), until equilibrium is reached again.[1]

Goldberg and Knetter (1997) discuss exchange rates and goods prices in a framework of *integrated* or *segmented markets*. They define an integrated market as one in which there are no systematic effects of geography or nationality on transaction prices for otherwise identical products. A good example of this is gold, a market in which the location of the buyers or sellers is basically irrelevant for the terms of the transaction. On the other end of the spectrum, there is the segmented market. This is one that lacks integration, and where the terms of the transaction is influenced by the location of the buyer and the seller by more than the marginal cost to physically move the good from one location to another. The authors use the automobile market as an example of a segmented market; additional taxes may be imposed between national borders and safety and environmental regulations may be differing between countries. In addition, if warranties and service are linked to the location of purchase, almost identical vehicles can be sold at different prices in different markets without resulting in arbitrage opportunities, leading to a violation of the law of one price. Two different national markets are thus segmented if buyers systematically face different prices in a common currency for the same product. A world market of a product is, on the other hand, characterized as integrated if the law of one price holds for all countries. If it holds between two countries, the absolute purchasing power parity (PPP) theory holds between them.

Exchange rate pass-through and pricing to market

The extent to which prices of imported goods react to nominal exchange rate movements can be defined as the *exchange rate pass-through*. For the law of one price to hold, it should be complete, which is the case when the import price is adjusted in full proportion to the exchange rate change. If the import price, on the other hand, responds in less than full proportion to the exchange rate change, the pass-through is incomplete. The practice of foreign firms to adjust their prices in domestic currency in a smaller proportion than the rise or fall of the exchange rate is known as *pricing to market*, as labeled by Paul Krugman (1987), and is essentially a price discrimination induced by exchange rates. When pricing to

[1] The review of the theory is based on Williamson (2008).

market occurs, the profit or loss stemming from the change in value of the domestic currency is absorbed by the foreign firm.

According to Krugman (1987), explanations for pricing to market behavior are the occurrence of imperfect competition, the possibility to price discriminate between different markets – i.e. the markets are segmented – as well as dynamics on both the supply and demand sides of the economy. The supply dynamics stem from the costs of rapidly adjusting the marketing and distribution infrastructure needed to sell the imported product. If the currency of the target market suddenly increases in value relative to that of the exporting country, there is no point in reducing the prices immediately if there is no capacity to meet the expanded demand. In addition, if the appreciation is expected to be temporary, the foreign firm will not find it worthwhile to expand its infrastructure to enable increased sales. From the perspective of the demand side, short-term price adjustments in response to exchange rate variations can be costly. A foreign supplier that unexpectedly raises its price because of a weakened destination market currency risks losing reputation and market shares.

Dwyer et al. (1994) state that the principal determinants of exchange rate pass-through, in the absence of other shocks, are the relative price elasticities of supply and demand. For imports, the degree of pass-through is expected to be higher the greater the elasticity of supply and the lower the elasticity of demand. Perfect market conditions should theoretically lead to a complete exchange rate pass-through in the case of a small open economy, i.e. a country engaging in international trade but whose activity is too insignificant to have an impact on the world market price. Imported goods into this country should be subject to perfect elasticity of supply, since the country is a price taker on the world market. Dwyer et al. (ibid.) further argue that, irrespective of the elasticities of supply and demand, the exchange rate pass-through can be affected by macroeconomic conditions. For example, when domestic demand is strong or capacity is constrained, the pass-through is expected to be high irrespective of the elasticities. Conversely, a weak domestic demand or low capacity utilization has a negative effect on the pass-through, since foreign suppliers are more likely to squeeze their margins in that macroeconomic environment.

Figure 1 below, as shown in Adolfson (1996), illustrates how different elasticities of demand affect this rate. Assume that D_1 represents an elastic demand curve in the importing country and S is the foreign firm's supply curve, resulting in the import price and quantity shown in point A. In a situation where the domestic currency weakens, customers are willing to pay

less in foreign currency for the imported product, shifting the demand curve down to D_1'. The resulting price and quantity is now displayed in point C. For a more inelastic demand, as shown by D_2, the exchange rate change leads to a shift in demand to D_2'. The new equilibrium is in point B, which corresponds to a higher price in foreign currency than in point C. The pass-through will thus be larger when domestic demand is more inelastic.

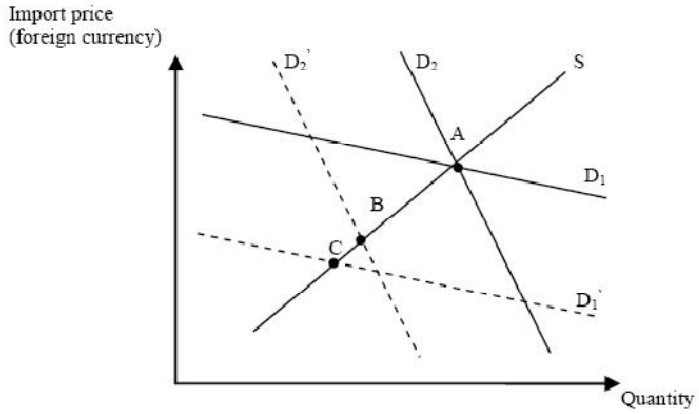


Figure 1. Exchange rate pass-through with different elasticities.

A practical implication of the pricing to market phenomenon is the limited effect that a rising or falling domestic currency will have on the external balance of payments and the domestic inflation. Krugman (1987) states that a declining domestic currency is expected to contribute to an increased inflationary pressure, but that the occurrence of pricing to market and thus an incomplete pass-through means that this effect will be overestimated. Hooper and Mann (1989) conclude that with an incomplete pass-through rate, a weakened domestic currency could be less effective in creating an adjustment in the external balance of payments, but they also mention the upside, which is the lower probability of a fueled inflation.

2.2 Previous empirical studies

In recent decades, a large number of studies have been performed that examine the relationship between exchange rate fluctuations and prices of imported goods. Initially, they were most often focused on larger economies such as the United States. From the mid 1990's and onwards, however, papers that examined small open economies became more common.

Menon (1993) studies the exchange rate pass-through to import prices of manufactured goods in Australia, using quarterly data between 1981 and 1992. He finds that the exchange rate pass-through is incomplete and that the import price responds only to a share of 66 percent of the exchange rate movement. The assumption of Australia as a price taker is thus rejected, contrary to the theory regarding small open economies. This is, according to Menon, a reasonable explanation of the fact that imports remained high following a strong depreciation of the Australian dollar in the mid 1980's (despite a high elasticity of import demand).

Dwyer et al. (1994) perform a similar examination with data from the time period 1974 to 1992. As opposed to Menon, they find a full long run pass-through (93 percent), which satisfies the case of the small country. In the shorter run, however, the import price response is incomplete. An exchange rate movement leads to an import price response with approximately 50 percent during the same quarter whereas full pass-through is reached in about one year. An explanation for the differing conclusions between Menon's study and that of Dwyer et al. is that in the latter, world export prices are used in the estimation instead of foreign production costs. The world price index becomes inappropriate for small economies since it corresponds to pricing decisions to all markets.

Another paper with the same issue in focus is one by Naug & Nymoen (1996), who study Norwegian import prices. They find a cointegration relationship between import prices, foreign prices, the exchange rate and domestic unit labour costs. The latter are used as an approximation of the prices of import competing goods. The long run pass-through in their study is 63 percent, which means that a 1 percent depreciation of the Norwegian Krona leads to an increase in import prices with 0.63 percent. The conclusions of their study are in accordance with the pricing to market hypothesis.

Adolfson (1996) conducts a study on the effect of exchange rate fluctuations on aggregate Swedish import prices with the Engle-Granger two-step procedure[2]. She uses aggregated monthly data from the period 1980:1 to 1995:5. Her conclusion is that the pricing to market hypothesis also holds for Sweden. However, she gets a negative sign in the regression. A pass-through of -69 percent indicates that a 1 percent depreciation of the Swedish Krona leads to an import price decrease of 0.69 percent, which is counterintuitive according to the theory.

[2] See chapter 4 for an explanation of the method.

In the dynamic model she constructs to examine short-run fluctuations, the immediate impact of a change in the exchange rate is 9 per cent, and within two months the pass-through is 22 per cent. An explanation for the wrong sign in the long-run regression could be that the time series is too short, since this method asymptotically should work according to the author[3].

In a later paper, Adolfson (1997) examines the same rate to Sweden on a disaggregate level, using Johansen's maximum likelihood procedure. The sample period is also in this case 1980-1995. She finds that the estimates of long-run pass-through indicate an incomplete rate in the majority of the eight industries in focus, with a gathering around 80 %. The average long-run pass-through for the sample is 65%. For oil prices, the pass-through is full and immediate, which supports the theory of the price a homogenous good traded on an integrated world market. The pass-through rate is also estimated for food (87 percent), metals (60), machinery (-278) as well as electrical machinery, transport equipment and chemicals, which are clustered around 85 percent.

Campa and Goldberg (2005) study exchange rate pass-through to import prices in 23 OECD countries, using quarterly data from 1975 to 2003. They estimate the average rate to 64 percent over the longer term for aggregate imports in the whole sample of countries. For Sweden, the number is 38 percent for the aggregate sample. They also estimate the disaggregated long-run pass-through rates to Sweden for food (85 percent), energy (-164), raw materials (11), manufactured (66) and nonmanufactured goods (-66).

Mishkin (2008) summarizes the findings of a number of previous studies on exchange rate pass-through – not including the Campa and Goldberg paper (2005) – and concludes that nominal exchange rate depreciation throughout history generally has been associated with higher inflation. More recent examples include the rapid currency depreciations and subsequent high rates of inflation that some countries experienced after the breakup of the Bretton Woods System. However, macro evidence from the last two decades suggest that the correlation between nominal exchange rate depreciation and consumer price inflation has indeed weakened significantly, which according to these studies is the result of improved monetary policies and more stably anchored inflation expectations[4]. To illustrate this he

[3] Personal communication, May 25th, 2010.

[4] See Mishkin (2008) p. 3-4 for a list of references.

compares two different periods of currency depreciation and the resulting inflation; the Swedish Krona depreciated with an average of 5 percent annually against the German Mark between 1973 and 1985, a period over which Sweden's annual inflation rate was around 4 percentage points higher than Germany's. When Sweden and the United Kingdom withdrew from the European Monetary System's Exchange Rate Mechanism (ERM) in 1992, on the other hand, inflation was low in both nations. In 1993 and 1994, the cumulative nominal depreciation of the Swedish Krona was 9 percent, whereas inflation only amounted to 3 percent. The pound fell by 15 percent over the same period, and the inflation in the United Kingdom was contained to 2 percent.

Campa and Goldberg (2005) also indeed find in their study that countries with lower exchange rate volatility and inflation have lower pass-through rates. Another interesting conclusion is that the rate has declined over time for many of the countries in the sample, a fact that according to the authors mostly stem from a change in the composition of the bundle of imports. When controlling for both exchange rate volatility and the type of goods that the countries import, it turns out that the latter is more important for explaining this decrease. Since pass-through for manufactured products generally is lower than for energy and raw materials, this change in weights has a negative effect on aggregate pass-through. The article does however not mention which of the countries in the sample that have decreasing rates over time, i.e. nothing is mentioned about Sweden in that matter.

Judging by the outcome of previous studies, a widespread consensus seems to be that the local prices of imported products in general do not respond to exchange rate changes to a full extent. In other words, the empirical results seem to refute the existence of the law of one price and the view of the world market to be integrated. Goldberg and Knettel (1997) summarize that the law of one price is mostly refuted, and add that "a significant portion of the muted price response can be attributed to destination-specific changes in markups on exports."

Other concluding remarks in Mishkin's (2008) review[5], are that the combination of *local currency pricing* (LCP), where the exporting firm sets the price of the good in the currency of the country to which it exports, together with nominal price rigidities, are partial explanations

[5] See Mishkin (2008) pp.8-11 for a listing of the papers he refers to.

for low exchange rate pass-through, particularly in the short run. This as opposed to *producer currency pricing* (PCP), which is the opposite situation and therefore implies a full pass-through. Following the LCP logic, it should be particularly low to a large economy like the United States. When studying the results of Campa and Goldberg (2005), larger economies like the United States and Germany do indeed show very low rates in most of the goods categories, but this negative relationship between country size and pass-through rate is not consistent throughout the sample. They find no significant relationship between country GDP and pass-through rate.

Regarding the discussion of how prices of imports affect consumer prices, Mishkin (2008) adds that *distribution costs* make up a substantial part of the retail price of imported goods. These are relatively insensitive to exchange rate shocks, which thus contributes to a reduction of the exchange rate pass-through to consumers. Finally, *cross-border production* can reduce the pass-through. In an internationalized economy, where production stages are separated into a number of different countries, the final good may incorporate costs in different currencies whose movements may not be positively correlated, resulting in a lower pass-through.

2.3 My contribution

After a look at previous literature on the subject, several factors have been reviewed as possibly influential on the exchange rate pass-through to import prices. The last of these studies included data until 2003. During the last decade, several events of strong macroeconomic significance have occurred that make a review of the exchange rate pass-through including more recent data interesting. One of them is the introduction of the euro. Among Sweden's ten largest trading partners throughout the last two decades, measured in import value, six are euro countries and have represented around 40 percent of the imports during this time period. Furthermore, two large economic crises, the dot-com bubble and the credit crisis, have occurred in the 2000s. The exchange rate-variability has been high for the SEK, displaying the typical pattern of a small currency over booms and recessions. Comparing with earlier decades, the annual inflation has also been very low.

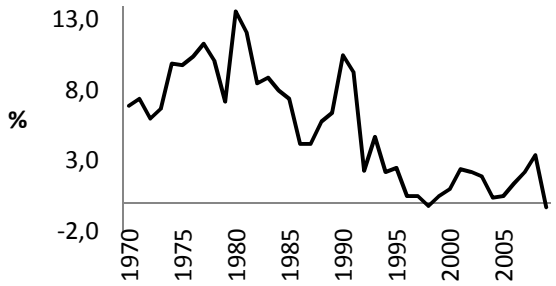


Figure 2. Annual inflation in Sweden 1970-2009. Source: SCB.

Considering the above, I will take a look at the exchange rate pass-through to aggregate Swedish import prices for the period 1990-2009. I want to examine whether pricing to market is present for this sample period, if the law of one price holds and also try to obtain an estimate of the pass-through rate. This will be done with the method and theory which are described in the two following chapters.

3 The method of cointegration analysis[6]

3.1 Stationary and nonstationary time series

Economic theories like the law of one price assume that there is a long-term, or equilibrium relationship, between the one hand the domestic price level (P^h) and on the other hand the foreign price expressed in domestic currency (EP^*). The same goes for exchange rate pass-through. If import prices are adjusted in full proportion to changes in the exchange rate, which is the definition of a full pass-through, there is a one to one relationship between import prices (P^m) and foreign prices measured in the importing country's currency (EP^*).

The movements of economic variables – such as the ones above – over time can be described as stochastic processes, since they are realized values that depend on the economic and political climate at the time being. A *stationary stochastic process* is one where the mean and variance of the series do not vary over time, i.e. the series tend to return to its mean and fluctuate within a more or less constant amplitude. If this is not the case, we call it a *nonstationary* variable. Economic variables, like those described above which are driven by

[6] This chapter is based on Gujarati (2003).

the supply of money, often show a nonstationary pattern over time. When a regression is run on two nonstationary variables, a relationship between them may be shown in the results, even if no meaningful connection exists. The variables may each be growing for different reasons and at uncorrelated rates. This is called spurious regression.

If a time series Y_t is nonstationary but becomes stationary when expressed in first difference form, or $\Delta Y_t = Y_t - Y_{t-1}$, the series is said to be integrated of the first order which is denoted as I(1). In another statistical terminology, it contains a unit root. If a time series need to be differenced twice to become stationary, it is integrated of the second order and contains two unit roots, and so on. When the differencing has to be done *d* times, Y_t is integrated of order *d*, which is written as I(d). A time series that is stationary without being differenced is integrated of order zero, I(0).

There is however the possibility that a linear combination of two nonstationary variables is stationary. If they move together, the linear combination cancels out the trend, and we get a meaningful regression. The variables are said to be cointegrated, and there exists a long-term, or equilibrium relation between them. A prerequisite for this, however, is that they are integrated of the same order. To be able to examine the exchange rate pass-through, we therefore need to test whether our variables are integrated of the same order. If this condition is fulfilled, we can analyze the relationships between the import price, the exchange rate, foreign producer prices, the activity in the Swedish economy and home market prices.

3.2 The Dickey-Fuller test

To test if a time series variable is stationary, a unit root test, also known as a Dickey-Fuller test, is performed. The value of a time series variable Y_t can be written as:

$$Y_t = \rho Y_{t-1} + u_t \tag{2}$$

where u_t is the error term. If $\rho = 1$, we have a so called random walk model where the value of Y_t equals Y_{t-1} plus a random shock caused by the error term. This time series will have a constant mean, but its variance increases over time and thus it is non-stationary. We can also say that when $\rho = 1$, the series contains a unit root. If, on the other hand, $|\rho| < 1$, the time series is stationary.

To be able to perform our analysis, we need to test if the time series we want to examine are stationary or not, in other words, to test the value of ρ. The equation is first rewritten; we subtract Y_{t-1} from both sides of the equation:

$$\Delta Y_t = \rho Y_{t-1} - Y_{t-1} + u_t = (\rho - 1)Y_{t-1} + u_t \quad (3)$$

which also can be written as

$$\Delta Y_t = \beta Y_{t-1} + u_t \quad (4)$$

where $\beta = (\rho - 1)$ and Δ denotes the first-difference. The unit root test is then performed to study whether β is significantly different from zero. If that is the case and β is negative, the series is stationary (β cannot take on a positive value since this would imply that $\rho > 1$). If β, on the other hand, equals zero, we conclude that it is non-stationary. Since the *t* value of the coefficient does not follow the *t* distribution under this test, but rather the τ (tau) distribution, the estimated β coefficient is compared to the relevant critical Dickey-Fuller values. There are three versions of the Dickey Fuller test, which should be performed if the actual nature of the time series is uncertain. One to test whether the series is a random walk:

$$\Delta Y_t = \beta Y_{t-1} + u_t \quad (5)$$

and two other versions to test whether it is a random walk with drift (equation 6 below) or a random walk with drift around a stochastic trend (7):

$$\Delta Y_t = \delta_1 + \beta Y_{t-1} + u_t \quad (6)$$

$$\Delta Y_t = \delta_1 + \delta_2 t + \beta Y_{t-1} + u_t \quad (7)$$

In all three cases, the tests are run with the null hypothesis that β is zero and that the series thus is non-stationary. Only the mean of the variable will be different between the three cases above.

The procedure is simply to estimate the above equations with the ordinary least squares method (OLS) and divide the estimated β coefficients with their standard error to receive the tau statistic. If the absolute value of the tau statistic exceeds the critical value, i.e. the β coefficient is significantly lower than zero, the series is stationary. If the error term is serially

correlated, we extend the test to do an augmented Dickey Fuller test, where lagged values of the dependent variable are included. In the case of equation (4), it looks as follows:

$$\Delta Y_t = \alpha + \beta Y_{t-1} + u_t + \sum_{i=2}^{m} \delta_i \Delta Y_{t-i} + \varepsilon_t \quad (8)$$

where ε_t is the error term and where lagged difference terms are added until the error term is serially uncorrelated. The null hypothesis is still the same is in the original equation. The serial correlation is tested with the Breusch-Godfrey (B-G) test, in which the residuals in the above equation are regressed on their own lagged values.

3.3 Cointegration analysis with the Engle-Granger test

We know that a linear combination of two non-stationary time series – but which are integrated of the same order – may be stationary, which is the case when their stochastic trends are cancelled out. This possible cointegration, or long-run relationship, can be examined with an Engle-Granger test. A variable, y_t, containing one unit root, regressed on another variable, x_t, which also has one unit root, will in the equation $y_t = \alpha x_t + u_t$ have a stationary residual, expressed as $u_t = y_t - \alpha x_t$, if the variables are cointegrated. The two steps of the Engle-Granger test are thus to:

1: Regress y_t on x_t in the equation $y_t = \alpha x_t + u_t$

2: Test if the residual $u_t = y_t - \alpha x_t$ contains a unit root with a Dickey Fuller test, by running the regression $\Delta \hat{u}_t = \beta \hat{u}_{t-1}$.

If the residual is stationary according to the Dickey-Fuller test, i.e. $\beta < 0$, the variables x_t and y_t are cointegrated.

4 Model of import price determination

With the practice outlined in the previous chapter, a cointegration analysis will be performed on a theoretical import price model described below.

4.1 Theoretical model

The theoretical framework, model specification and setup of possible cointegration relationships presented in this chapter is based on Hooper and Mann (1989) and has been commonly used in previous papers on exchange rate pass-through[7]. The definition of the pass-through, as used in this analysis, is the partial derivative of the import price with respect to the nominal exchange rate.

We illustrate the determination of the import price by seeing it as a variable which is deduced from the producer's marginal cost together with a markup that is specific to the destination market. Because of the market dynamics discussed previously, foreign suppliers are expected to have some degree of control over their price setting, which results in a price above marginal cost. The price in the foreign producer's currency thus becomes:

$$P^* = \lambda C^* \tag{9}$$

By multiplying the foreign currency price with the nominal exchange rate, we get the import price in the importing country's currency:

$$P^m = EP^* = E\lambda C^* \tag{10}$$

The markup is variable and dependent on the level of competition among suppliers as well as the demand pressure on the market. A proxy for the level of competition is the ratio between the general price level for import competing goods (here the home market price index, P^h) divided by the foreign company's production costs measured in domestic currency. The higher the ratio, the larger is the markup. Another factor to take into account is the demand pressure on the destination market, since a higher demand means a possibility set a higher price. We therefore let the GDP be an approximation for demand.

[7] Hooper and Mann (1989), Menon (1995), Adolfson (1996), Adolfson (1997), Wickremasinghe and Silvapulle (2004)

The markup can thus be written as:

$$\lambda = \left(\frac{P^h}{C^* E}\right)^{\alpha} \times GDP^{\beta} \tag{11}$$

Inserting equation (11) into equation (10) lets us express the import price as:

$$P^m = E \times C^* \left(\frac{P^h}{C^* E}\right)^{\alpha} \times GDP^{\beta} \tag{12}$$

We rewrite the equation in logarithmic form, and express logarithmic values with lower-case letters:

$$p^m = e + c^* + \alpha\left(p^h - e - c^*\right) + \beta gdp \tag{13}$$

Production costs of the foreign supplier are approximated with an index over foreign producer prices (p^f). The Activity Index (ai in logarithm values) is used as a proxy for gdp:

$$p^m = e + p^f + \alpha\left(p^h - e - p^f\right) + ai \tag{14}$$

After rearranging, we get:

$$p^m = (1 - \alpha)e + \alpha p^h + (1 - \alpha)p^f + \beta ai \tag{15}$$

The pass-through coefficient $(1 - \alpha)$ denotes the extent to which an exchange rate change affects the import price. If $\alpha = 0$, the pass-though is complete and the exchange rate fluctuation is fully passed through to the import price. As can be seen in equation (15), this value of the α coefficient also means that home market conditions (p^h) are irrelevant for the determination of the import price. When $\alpha = 1$, on the other hand, the pass-through is zero. In this case, an exchange rate change has no effect on the import price, and will be absorbed by the foreign producer's profit margin. In this situation, the domestic price level determines the import price.

Equation (15) can be rewritten to show the profit margin as a function of the home market price and the foreign production costs. When $\alpha > 0$, a depreciation of the local currency's value relative to the foreign producer's means that, ceteris paribus, its profit margin is reduced;

(16) $$p^m - e - p^f = \alpha(p^h - e - p^f) + \beta ai$$

4.2 Possible cointegration relationships

Derived from the theory and equations in the previous chapter, we can now set up three possible cointegration relationships that we will examine with the Engle-Granger test:

$$H_{0,1} : p^m - e - p^f \sim I(0)$$

The above hypothesis will be tested to find out if pricing to market is present in our sample of Swedish import prices. If the pass-through is complete, a cointegration relationship exists between import prices in SEK (p^m) and foreign producer prices measured in SEK ($e + p^f$). The import price will then be adjusted in response to exchange rate fluctuations, so that the relationship over time returns to a mean which is constant. Written in log-linear form, this will result in an integration of zero order, I(0), of the variable $PTM = p^m - e - p^f$ which equals our null-hypothesis above. If import prices to Sweden, on the other hand, do not respond in full proportion to an exchange rate change, the PTM variable will be non-stationary. This is the case when pricing to market is prevalent. This is easy to see when looking at $H_{0,1}$ above and imagining an increase in e while p^m and p^f remain constant. The ratio between them will then change over time.

Our second null-hypothesis originates from the theory of the law of one price. We will examine if it holds or can be refuted, with the test:

$$H_{0,2} : p^h - e - p^f \sim I(0)$$

This is the ratio between the general price level in Sweden for import competing goods (P^h) and foreign producer prices measured in domestic currency ($e + p^f$), and as mentioned previously, it is used as a proxy for the level of competition on the Swedish market. Referring to the theory, if the law of one price holds so that, written linearly, P = EP*, the relationship between the variables should be constant, i.e. P/EP* = 1. If the variables are cointegrated, the law of one price holds. Otherwise, this relationship is violated.

If it turns out that neither H_1 nor H_2 holds, there is still a possibility that a relationship exists such that a combination of them is stationary. This is expressed as:

$$H_{0,3} : (p^m - e - p^w) - \alpha(p^h - e - p^f) - \beta ai \sim I(0)$$

An interpretation of $H_{0,3}$ is that if the ratio (p^m - e – p^f) between import prices and foreign producer prices is changing – i.e. pricing to market is prevalent which results in a changing profit margin for the foreign firm when the exchange rate changes – an explanation is found in a changing competitive environment (p^h – e – p^f) and demand (ai). The last equation will also allow us to obtain an estimate of the pass-through rate (1-α).

5 Data

For the empirical analysis, monthly data for the period January 1990 to December 2009 has been collected. Indices over import prices and home market prices have been gathered from Statistics Sweden (SCB). From nine different goods categories, aggregate import price and home market price indices have been constructed for the sample period, weighted with the import shares of the respective categories. The reason that I simply did not use total price indices is that I hoped to be able to match these composed indices better with the foreign producer price indices that were used. The latter were retrieved from the OECD Main Economic Indicators database and the included sample consists of producer price indices from the ten[8] largest exporting countries to Sweden, weighted against each other with their internal distribution of import shares. Ideally, the analysis should be done with producer costs, but since I could not find such indices, producer prices were used as approximations.[9]

As a proxy for the exchange rate between the SEK and the currencies of Sweden's trading partners, the TCW index from the Riksbank is used. This is constructed to reflect the value of the SEK versus a weighted composition of currencies representing Sweden's largest trading partners.

[8] These countries are Belgium, Denmark, Finland, France, Germany, Great Britain, Italy, the Netherlands, Norway and United States.

[9] See appendix for a detailed description of the import, home market and foreign producer price index.

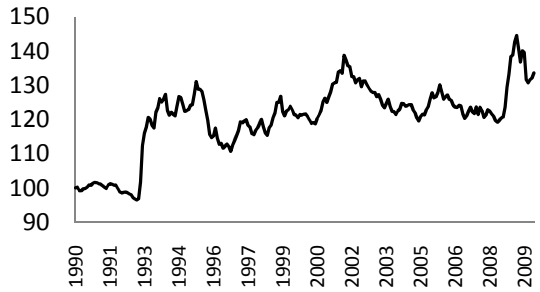


Figure 3. The TCW index.

As an approximation of the demand on the Swedish market, the GDP intuitively seems most appealing. Since it is measured quarterly data, however, the seasonally adjusted Activity Index from SCB is employed in this analysis. This is a monthly index measuring industrial production, hours worked in government agencies, sales in retail trade, and exports and imports of goods[10]. This index is in most senses identical to GDP, but does not include investments and exports and imports of services. All indices used in the analysis have been normalized so that January 1990 is the default value.

6 Empirical results

6.1 Integration order of the variables

A look at figure 4 to 8 below, which depict logarithmic index values of our series, suggest that the variables exhibit an increasing trend over time and are non-stationary. Due to the obvious nature of the time series, an augmented Dickey-Fuller test with a constant and a trend is carried out.

[10] The Activity Index has been discontinued by SCB as of February 2010 due to "uncertainty about the data quality", according to the web page. However, since the index values are adjusted as soon as the latest GDP measurement is published, they should be a good monthly approximation for the GDP ex post.

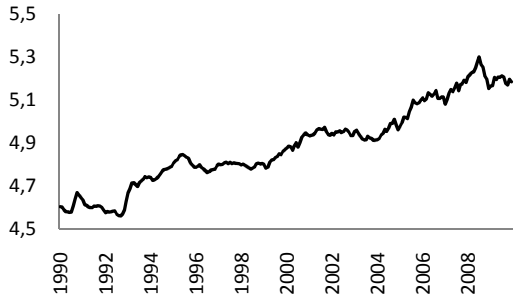


Figure 4. Logarithm values of the aggregate import price index.

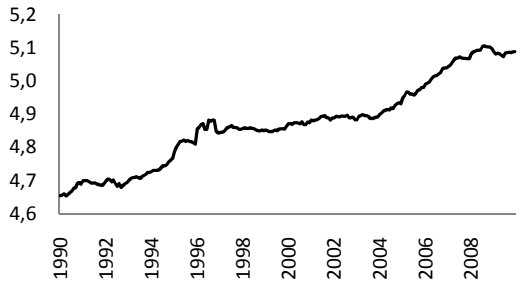


Figure 5. Logarithm values of the aggregate home market price index.

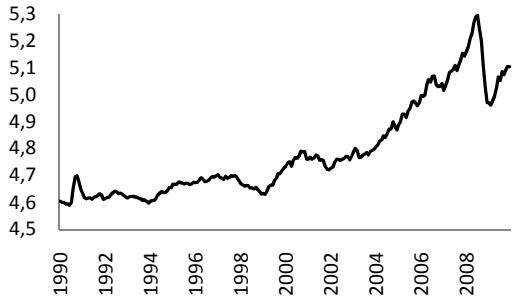


Figure 6. Logarithm values of aggregated foreign producer prices.

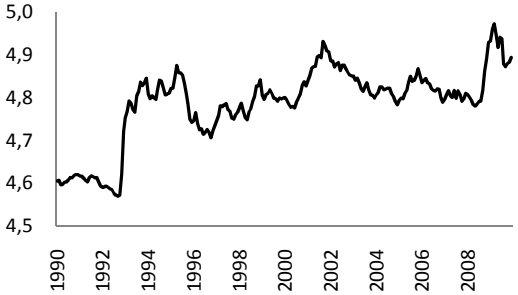


Figure 7. Logarithm values of the Swedish TCW-index.

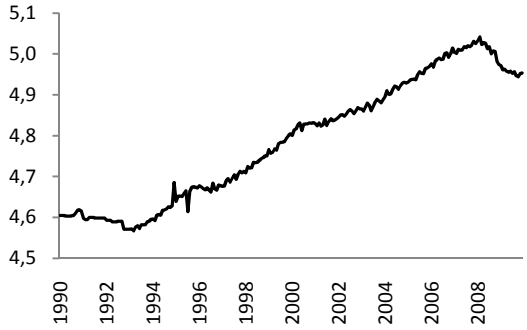


Figure 8. Logarithm values of the Activity Index.

The results of these tests confirm that all series are nonstationary. None of the null-hypotheses that the series contain a unit root is rejected. In other words, all the variables are integrated of at least the first order and thus contain one or more unit roots. The examinations whether the series are integrated of a higher order than the first are then done with Dickey Fuller tests on the first-difference of the variables. We can see from *table 1* that this is not the case, since we can reject each null-hypothesis of nonstationarity on the one percent level for all variables. The conclusion is therefore that since all the variables are integrated of the same order, i.e. contain one and only one unit root, they can also be cointegrated.

Variable	Level ADF Statistics	β1 estimate	H_0	Number of lags	B-G	First difference ADF Statistics	β1 estimate
p^m	-2.95	-0.056	Not rejected	1	1.17	-9.51	-0.79
p^h	-1.69	-0.022	Not rejected	1	0	-10.01	-0.88
p^w	-2.58	-0.031	Not rejected	1	0.71	-7.34	-0.50
e	-2.80	-0.042	Not rejected	1	0	-9.41	-0.71
ai	-0.40	-0.002	Not rejected	1	1.90	-16.35	-0.87

Table 1. Augmented Dickey-Fuller test with intercept and time trend. The critical values to reject H_0 are -3.99 (1% level) and -3.43 (5%). For the B-G test, a value above of 3.84 means that we can reject the null-hypothesis of no autocorrelation on the 5% level. The 1% level value is 6.63.

6.2 Cointegration results

Pricing to market

If import prices to Sweden are adjusted in full proportion to an exchange rate change, the ratio between these (p^m) and the foreign producer prices measured in SEK ($e + p^f$), will be constant. In other words, the variable $PTM = p^m - e - p^f$ will be stationary, as formulated in the null-hypothesis $H_{0,1}$. A plot of this variable is displayed in figure 9.

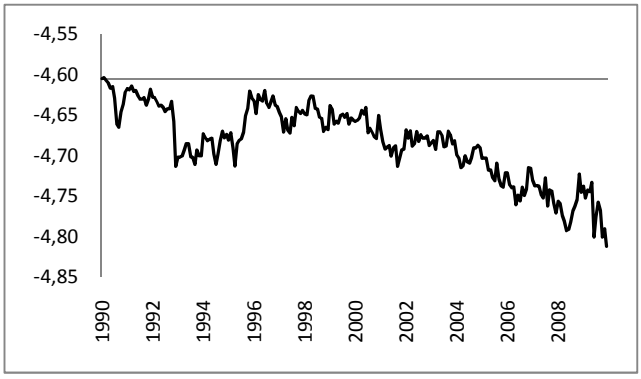


Figure 9. Logarithm values of $p^m - e - p^w$.

We can observe a decreasing tendency of the PTM variable over time. A strong decrease occurred in 1992 when the SEK was changed from fixed to floating, which shows that Swedish import prices did not increase in the same proportion as the SEK depreciated due to the float. An almost equally incomplete pass-through occurred when the SEK recovered in 1995-1996. The Dickey-Fuller tests confirm nonstationarity of the time series and the fact that pricing to market is present.

Variable	Level DF Statistics	β1 estimate	Reject H_0	Number of lags	B-G	First difference ADF Statistics	β1 estimate
$p^m - e - p^w$	-1.79	-0.034	No	0	0.952	-13.12	-1.33

Table 2. Dickey-Fuller test with intercept. Critical values: -3.75 (1%) and -3.00 (5%). Critical B-G values: 3.84 (5%), 6.63 (1%).

The law of one price

To examine whether the law of one price, or the purchasing power parity, holds between Sweden and its foreign trading partners, we examine the relative price level $p^h - e - p^f$ plotted below.

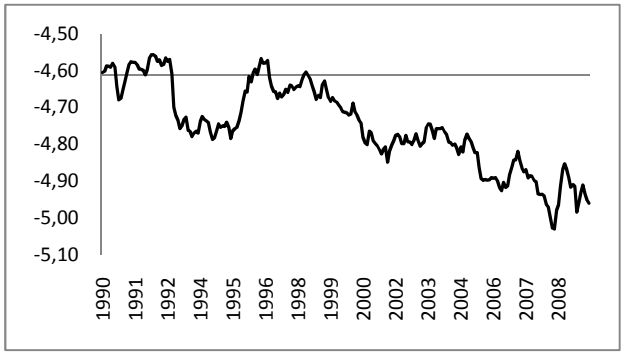


Figure 10. Logarithm of the relative price $p^h - e - p^f$.

Like the PTM variable it shows a decreasing trend, and its non-stationarity cannot be rejected by the Dickey-Fuller test. We can therefore conclude that the law of one price is rejected.

Variable	Level ADF Statistics	β1 estimate	Reject H_0	Number of lags	B-G	First difference ADF Statistics	β1 estimate
$p^h - e - p^w$	-1.364	-0.015	No	1	0. 0	-9.713	-0.777

Table 3. Augmented Dickey-Fuller test with intercept. Critical values: -3.75 (1%) and -3.00 (5%). Critical B-G values: 3.84 (5%), 6.63 (1%).

We also want to examine if there is a cointegration relationship between the home market price, the exchange rate and foreign producer prices, as expressed in $H_{0,2}$. The regression of home market prices on the exchange rate and foreign producer prices gives us the following estimation results:

(17) $p_t^h = 0.452e_t + 0.556p_t^f + u_t$

Standard error	(0.015)	(0.015)
t statistics	(29.938)	(36.843)

To examine a possible cointegration relationship, we do a Dickey-Fuller test on the residual, which is shown below.

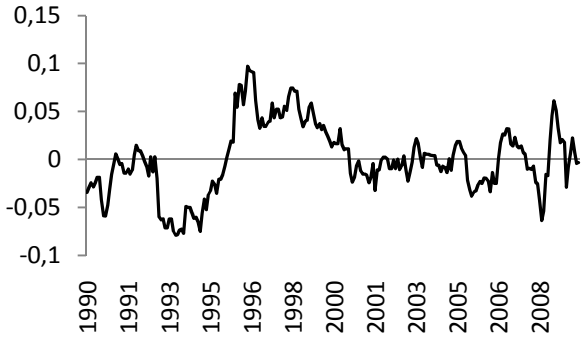


Figure 11. Residual of the relative price regression (17).

Variable	Level ADF Statistics	β1 estimate	Reject H_0	Number of lags	B-G	First difference ADF Statistics	β1 estimate
u_t	-2.71	-0.057	No	1	0,0	-9,713	-0,777

Table 4. Augmented Dickey-Fuller test with intercept. Critical values: -3.75 (1%) and -3.00 (5%). Critical B-G values: 3.84 (5%), 6.63 (1%).

The Dickey-Fuller test about nonstationarity cannot be rejected. The mean appears to be constant, but the variance is changing over time. In the case of stationarity between the variables, the coefficient of 0.452 would tell us that a change in value of the SEK with 1 percent leads to a change in the home market price in Sweden with 0.452 percent, when the foreign producer price is held constant.

Pricing to market and the relative price

Even if pricing to market is present and the law of one price violated, there can still be a relationship such that the import price is explained by the relative price level between Sweden and other countries. To study if this the case, a cointegration test is done between the import price relative to foreign producer prices $(p^m - e - p^f)$ and the relative price between the

Swedish and foreign markets $\alpha(p^h - e - p^f)$. A stationary relationship between these variables is how the null-hypothesis $H_{0,3}$ was expressed.

To obtain α, we do the regression:

$$(p_t^m - e_t - p_t^w) = \alpha\left(p_t^h - e_t - p_t^f\right) + \beta a i_t + u_t$$

and get the following result:

$$(p_t^m - e_t - p_t^w) = 0.986\left(p_t^h - e_t - p_t^f\right) + u_t$$

Standard error	(0.001)
t statistic	(1003.140)

Given that the residual is stationary, this would mean that when the relative price increases with 1 percent, the relationship $\left(p_t^m - e_t - p_t^f\right)$ increases with 0.986 percent. This value of α gives a pass-through coefficient of (1– 0.986) = 0.014, meaning that home market conditions will be decisive for the pass-through.

A plot of the residual $u_t = \left(p_t^m - e_t - p_t^f\right) - 0.986\left(p_t^h - e_t - p_t^f\right)$ in the figure below however shows that it tends to fluctuate around a constant mean during the first half of the sample, but that this mean appears to increase as we move forward in the time period.

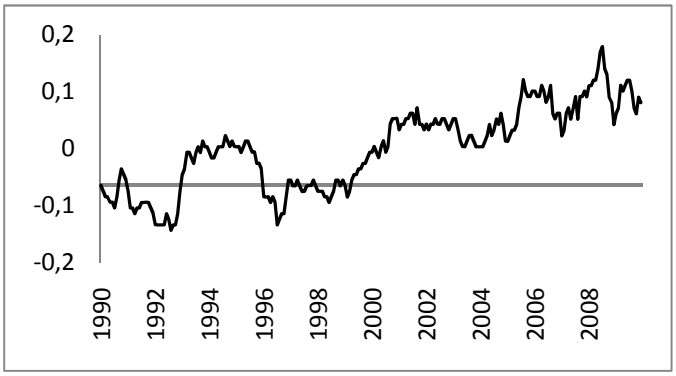


Figure 12. The linear combination $(p^m - e - p^f) - \alpha(p^h - e - p^f)$.

The Dickey-Fuller test confirms this suspicion. The error-term is non-stationary, which leads us to the conclusion that variables are not cointegrated.

Variable	Level, ADF Statistics	β1 estimate	Reject H_0	Number of lags	B-G	First difference ADF Statistics	β1 estimate
p^m - e – p^f-$\alpha(p^h$ - e $p^f)$	-1.7692	-0.023	No	1	0.952	-10.1047	-0.869

Table 4. Augmented Dickey-Fuller test with intercept. Critical values: -3.75 (1%) and -3.00 (5%). Critical B-G values: 3.84 (5%), 6.63 (1%).

A rejection of $H_{0,3}$ is problematic for our analysis since a nonexistence of cointegration between the variables means that the regression of $(p_t^m - e_t - p_t^f)$ on $(p_t^h - e_t - p_t^w) - ai_t$ is spurious and the pass-through coefficient (the α estimate) is not meaningful. Given our data and methodology, we are unable to estimate the exchange rate pass-through to aggregate Swedish import prices.

6.3 Discussion of the results

In the results of our aggregate sample of import product categories, we could conclude that pricing to market is present in imports to Sweden throughout the sample, meaning that import prices do not react in full proportion to a change in the exchange rate. It shows that exporters can set different prices in a common currency to different markets because they are segmented and prohibit arbitrage opportunities. This is in line with previous studies on the exchange rate pass-through and confirms that theories seeing the small open economy as a price taker contradicts the growing empirical literature.

Neither is the relative price between products on the home and foreign market constant, as tested in $H_{0,2}$ and the law of one price can therefore be rejected. Examining the relationship between the included variables – the home market price, the exchange rate and the foreign producer price – the test rejected our null-hypothesis of cointegration.

Moreover, no cointegration existed between the relative price level and the profit margin of the foreign firm, expressed in $H_{0,3}$. We were thus not able to compute the exchange rate pass-through, defined as $(1 - \alpha)$ in the main equation:

$$p^m = (1 - \alpha)e + \alpha p^h + (1 - \alpha)p^f + \beta ai.$$

In my data sample, I chose to include the ten largest exporters to Sweden during 1990-2009. The ranking of the largest exporters has of course changed over time and in 2009 alone, China, was the eight largest exporter to Sweden in terms of value of imported goods. If

countries whose parts of the import price indices have increased while their producer prices are not matched properly, the data can of course be distorted relative to that we want to measure.

Lack of foreign data on a properly detailed level and the approximations that have to be done can be another problem. In my aggregate sample[11], e.g., computers, which have shown a decreasing trend in price level, was a large category in the import and home market price, whereas it is unclear exactly how the OECD Main Economic Indicators for individual countries are composed[12].

7 Conclusions

In this paper, I have examined the relationships between weighted aggregate price indices for imports, the home market, the exchange rate and foreign producers, with the ambition to obtain an estimate of an aggregate exchange rate pass-through for import prices to Sweden. Using an established theoretical model that expresses the import price as a function of the competitive situation and the demand on the destination market, the Engle-Granger two step procedure is carried out to examine possible cointegration relationships between the variables. It could be concluded that pricing to market is present for Swedish imported goods and that the law of one prices is violated for this time period. Furthermore, no cointegration exists in a linear combination including all variables, which is necessary to obtain an estimation of the pass-through, confirmed not to have arisen because of spurious regression.

During the 2000's, several significant macroeconomic events have occurred that makes a review of the exchange rate pass-through mechanism to Sweden interesting. A large number of Sweden's most important trading partners have introduced a common currency. Furthermore, the fluctuation in economic activity and the slump following the deep recession

[11] I collected data for different industries and constructed a weighted aggregate sample instead of just looking for total imports and producer prices. The reason for this was that I wanted to examine the pass-through rate on the disaggregate level as well. However, when testing for cointegration for manufactured goods, the results were the same as for the aggregate sample, i.e. the variables were not cointegrated.

[12] No detailed information on the composition of goods in the samples is provided on the OECD webpage.

after the credit crisis is of historic proportion. A reduction in inflation due to an improved monetary policy and anchored inflation expectations might also contribute to the direction of the pass-through. I was however not able to discern the net effect of these factors with the methodology used in this paper and therefore leave it to future research.

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Appendix

Definitions of the price indices

- p^m = Weighted aggregate Swedish Import price index. Jan 1990 = 100. Source: SCB, Statistics Sweden.

- p^h = Weighted aggregate Swedish Home market price index. Jan 1990 = 100. Source: SCB, Statistics Sweden.

The above weighted aggregate indices were constructed from individual indices of the following SPIN 2007 categories:

- 6.1Crude petroleum
- 10 Food products
- 20 Chemicals and chemical products
- 24 Basic metals
- 26 Computer, electronic and optical products
- 27 Electrical equipment
- 28 Machinery and equipment n.e.c.
- 29 Motor vehicles, trailers and semi-trailers
- 30 Other transport equipment

The weighing is based on import shares in 2009 which were distributed as follows:

Crude petroleum	6.4%
Food	11.2%
Chemicals	16.3%
Basic metals	9.1%
Industrial products (26-30)	57.0%

- p^f = Weighted aggregate foreign producer prices in Belgium, Denmark, Finland, France, Germany, Great Britain, Italy, the Netherlands, Norway and the United States. Constructed with weights based on import shares to Sweden in 2009. Chemicals and industrial products are approximated with producer prices in manufactured goods. For crude petroleum and basic metals, world market price indices are used. Source: OECD for producer prices and SCB, Statistics Sweden for import shares.

The country weights are distributed in the following way:

Belgium	6.03%
Denmark	10.53%
Finland	5.88%
France	8.84%
Italy	4.02%
The Netherlands	9.93%
Norway	12.42%
Great Britain	8.14%
Germany	28.47%
United States	5.75%