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Contents

Abstract

This paper investigates the pass-through of external shocks, i.e. oil price shocks, exchange rate shocks, and non-oil import price shocks to euro area inflation at different stages of distribution (import prices, producer prices and consumer prices). The analysis is based on a VAR model that includes the distribution chain of pricing. According to our results the pass-through is largest and fastest for non-oil import price shocks, followed by exchange rate shocks and oil price shocks. The size and the speed of the pass-through of these shocks decline along the distribution chain. External shocks explain a large fraction of the variance in all price indices. They seem to have contributed largely to inflation in the euro area since the start of the European Monetary Union. The results on the size and the speed of the pass-through in the euro area appeared to be robust over time and different identification schemes.

JEL Classification: C32, E31

Keywords: Pass-Through, Exchange Rate, Oil Price, Import Price, Euro Area Inflation

Non-technical Summary

Thorough knowledge of the underlying relationship between exchange rates and prices, i.e. of the exchange rate pass-through, is of particular importance for monetary policy. Both the size of the pass-through and its speed are essential for the proper assessment of the monetary policy transmission on prices as well as for inflation forecasts. In view of the large movements of the exchange rate of the Euro since the launch of the European Monetary Union (EMU) in 1999 the pass-through is also of special interest for the monetary policy of the European Central Bank (ECB). Besides the strong depreciation of the Euro since 1999 the euro area was also hit by further external shocks, namely, shocks to oil prices and to non-oil import prices. For the proper assessment of price developments and risks to price stability also the size and speed of the pass-through of these shocks on inflation in the euro area seem of great interest. However, to date the empirical evidence on the pass-through of external shocks on euro area inflation is still very rare.

This paper aims at contributing to fill the gap in empirical evidence on the pass-through of external shocks on euro area inflation. A comprehensive analysis of the pass-through of changes in the exchange rate, oil prices and non-oil import prices to inflation at different stages of distribution, i.e. on non-oil import prices, producer prices and consumer prices, is undertaken. Including prices along the distribution chain seems of great interest for euro area price analysis as it reveals how external shocks are propagated from one price stage to the next. The analysis is conducted within a Vector Autoregression (VAR) model, which is well suited to capture both the size as well as the speed of the pass-through. In the baseline model identification is achieved through a Choleski decomposition. The analysis is based on euro area wide data.

Information on the size and the speed of the pass-through is derived from impulse response functions. According to our results as regards all price indices the pass-through is largest and fastest for non-oil import price shocks, followed by exchange rate shocks and oil price shocks. The size and the speed of the pass-through of external shocks decline along the distribution chain. Comparing our results to those of other studies our estimate for the total pass-through of exchange rate shocks on import prices of 50 percent (after 3

quarters) seems to be broadly in line with the findings of *Anderton (2003)*. The total effect of exchange rate shocks on the HICP of 16 percent is twice as large as estimated by *Hüfner and Schröder (2002)*. Variance decompositions indicate that external shocks account for quite large fractions of the variance in all price indices. Historical decompositions for the time period since the start of the EMU show the external shocks seem to have contributed strongly to increase inflation in the euro area since 1999.

The robustness of these results was tested in two ways. First, the robustness of the results over time was analyzed by estimating the model over two subsample periods. The size and the speed of the pass-through appeared to be stable over the two subsamples. Variance decompositions over the different periods indicate that the relative importance of external shocks for fluctuations in the different price indices in the euro area seems to have increased over time. Similar observations were reported by *McCarthy (2000)* for a number of industrialized countries. A potential explanation for these developments might be a greater focus of monetary policy on stabilizing the domestic sources of variation in prices in recent years. The estimates as regards the exact contributions of external shocks to inflation in the euro area since 1999 varied substantially across different sample periods. A common result from different sample periods was however that external shocks were strong positive contributors to inflation in the euro area since the start of the EMU. Second, as it is well-known that the results derived from VAR models may strongly depend on the underlying identification scheme, the robustness of the results across different identification schemes was investigated. It turned out that the results were very robust as regards different plausible orderings in the Choleski decomposition. Almost identical results as regards the responses of the different price indices to oil price shocks, and somewhat smaller effects as regards those to exchange rate and non-oil import price shocks were furthermore derived from a model including short and long-run economic restrictions.

1 Introduction

Thorough knowledge of the underlying relationship between exchange rates and prices, i.e. of the exchange rate pass-through[1], is of particular importance for monetary policy. Both the size of the pass-through and its speed are essential for the proper assessment of the monetary policy transmission on prices as well as for inflation forecasts. In view of the large movements of the exchange rate of the Euro since the launch of the European Monetary Union (EMU) in 1999 the pass-through is also of special interest for the monetary policy of the European Central Bank (ECB).

A large body of empirical literature deals with the exchange rate pass-through to prices (see e.g. the comprehensive survey of *Menon (1995)* summarizing the results of 43 papers or the studies of *Kahn (1987)*, *Kenny and McGettigan (1998)*, *Kim (1998)*, *McCarthy (2000)* and *Campa and Goldberg (2002)* to name but a few). The primary objective of most of these studies is the assessment of the degree and dynamics of the pass-through. In this respect most studies find incomplete pass-through to prices even in the long-run often combined with quite substantial lags in the adjustment process. Aside from the size and speed of the pass-through, the stability of the pass-through relationship over time is of utmost interest. A number of studies that address this issue report a decline in the pass-through for a variety of countries since the 1980s (see e.g. *Gagnon and Ihrig (2002)* and *Taylor (2000)*).

Recent developments in the euro area seem to indicate that these results apply also to the new Euro currency area. The large depreciation of the Euro vis-a-vis major currencies in 1999 and 2000 does not seem to have affected euro area inflation very strongly. Yet empirical evidence on the exchange rate pass-through to prices in the euro area is still rare. To our best knowledge to date only three studies were concerned with the degree of the exchange rate pass-through to either import prices or consumer prices in the euro area.

First by employing both time series and panel methods *Anderton (2003)* analyzes

[1] According to *Menon (1994)* exchange rate pass-through is defined as "the degree to which exchange rate changes are reflected in the destination currency prices of traded goods."

the pass-through of changes in the effective exchange rate of the Euro to extra-euro area import prices in manufacturing. His results indicate a pass-through of around 50 to 70 percent. At least half of the impact is passed through within one quarter, while most of the effect occurs after about five quarters. Regarding the exchange rate pass-through to euro area consumer prices *Ranki (2000)* using an OLS regression approach finds complete pass-through within a single month, a result that strongly contradicts recent observations for the euro area. Finally *Hüfner and Schröder (2002)* analyze the exchange rate pass-through to consumer prices in the five largest countries of the euro area by applying a Vector Error Correction Model (VECM). Approximations for the euro area are then derived as a weighted average of the country results. Their results indicate a rather modest pass-through of four percent after one year, which rises to its long-run level of eight percent after about three years.

This paper aims at contributing to fill the gap in empirical evidence on the euro area exchange rate pass-through. Besides the strong depreciation of the Euro since 1999 the euro area was also hit by shocks to oil prices and non-oil import prices. The impact of these shocks on euro area inflation has not been quantified in empirical studies so far. As a result in this paper a comprehensive analysis of the pass-through of external shocks to domestic inflation in the euro area is undertaken. This analysis comprises the pass-through of changes in the exchange rate, oil prices and non-oil import prices to non-oil import, producer, and consumer prices in the euro area. Thus the pass-through to each stage of the distribution chain (import, producer, and consumer prices) is covered. This exercise is of great interest for euro area price analysis as it reveals how external shocks are propagated from one price stage to the next. The analysis is conducted within a Vector Autoregression (VAR) model. This framework allows for underlying dynamic interrelations among prices at different stages of distribution and other variables of interest. It furthermore enables to trace the dynamic responses of prices to external shocks, i.e. it captures both the size as well as the speed of the pass-through. In the baseline model identification is achieved through a Choleski decomposition. The analysis is based on euro area wide data. The basic setup of the model partly follows the framework of *McCarthy (2000)*, who analyzed the pass-through in selected industrialized countries at all stages of the distribution chain.

The following analytical tools are used to explore the impact of external shocks on domestic inflation in the euro area: Impulse responses are provided to analyze the size and speed of the pass-through of external shocks on the different price indices. Variance decompositions are computed to capture the relative importance of external shocks in explaining fluctuations in the price indices. Furthermore historical decompositions are used to assess the size of the (dis)inflationary impact of external shocks that occurred since the start of the European Monetary Union (EMU) on inflation in the euro area.

Finally, the robustness of the achieved results is investigated. This is done in two ways. First, the robustness of the results over time is examined by estimating the model over different sample periods. Second, the robustness across different identification schemes is analyzed. Different plausible orderings of the variables in the Choleski decomposition as well as an identification scheme that includes both short and long run restrictions are taken into account.

The rest of the paper is organized as follows: Section 2 provides a short overview of important theoretical considerations relating to the pass-through of external shocks to domestic inflation at different stages of distribution. In section 3 the data set and the data properties are discussed. Section 4 presents the baseline model used for the empirical analysis and its results. The robustness analysis is conducted in section 5. Section 6 concludes.

2 Theoretical Background

This section intends to give some theoretical background information on the pass-through of external shocks to domestic inflation at different stages of distribution. To this end, in the following, first, some theories, that provide insights into the pass-through of shocks on prices in general, are briefly mentioned. As an important part of our analysis refers to the pass-through of exchange rate shocks, a further part of this section shortly reviews important aspects of this literature. Finally, since the analysis in this paper centers on the pass-through at different stages of distribution, theoretical considerations relating to this issue are presented.

With regard to the first point, in the context of imperfect competition the pass-through of (external) shocks to prices may be strongly affected by the behavior of the markups of prices over marginal costs. A large number of models deal with the behavior of markups. To follow *Rotemberg and Woodford (1999)* theoretical models of variable markups include New Keynesian sticky price models as well as models of variations in desired markups. As regards the former, sticky prices may result from factors like menu costs or staggered price setting as suggested by *Taylor (1980)* and *Calvo (1983).* Under the assumption of sticky prices, cost shocks affect prices to a lesser extent than marginal costs. These changes in the markup dampen the pass-through. In the latter category of models changes in desired markups may result from a number of different sources such as variations in the elasticity of demand, the (threat of an) entry of new firms into a market (see, e.g., *Chatterjee, Cooper and Ravikumar (1993)* and *Portier (1995)*) or intertemporal profit maximization considerations (compare the "consumer market" model by *Phelps and Winter (1970)* or the "implicit collusion" model of *Rotemberg and Woodford (1992)*).

A further determinant of the pass-through is brought forward by *Taylor (2000).* According to *Taylor (2000)* the perceived persistence of shocks affects the size of the pass-through. Firms adjust their prices to a lesser extent to cost and price developments that are expected to be more volatile. In this context *Taylor (2000)* furthermore provides an explanation for potential changes of the pass-through over time. He argues, that a change to a lower inflation environment e.g. due to a new monetary policy regime, via a reduction in the expected persistence of cost and price shocks, may entail a lower pass-through of shocks to prices.

A number of complementary theories provide insights into the exchange rate pass-through.[2] This literature includes for instance the the elasticities approach, that explains the size of the exchange rate pass-through to import prices by means of the elasticities of the demand and supply of imports. As these elasticities are strongly affected by the

[2]A comprehensive analysis of the theories on the exchange rate pass-through is provided by *Menon (1995).* Further factors that may affect the exchange rate pass-through in the short-run and thus the speed of adjustment are summarized in *Menon (1994).*

size and the openness of a country, this theory predicts complete pass-through for small open economies and incomplete pass-through for large closed economies. Moreover, also the exchange rate pass-through literature considers the case of imperfect competition. In response to exchange rate shocks firms can basically choose between keeping their markup or their foreign currency price constant (pricing to market). The degree to which they are willing to accept changes in their markup depends on their pricing power which in turn is strongly determined by factors like the product differentiation and the degree of the market integration (see *Dornbusch (1987)* and *Fischer (1989)*). In addition, according to the so-called "hysteresis models" as a result of large exchange rate changes it may be profitable for firms to accept the costs associated with the exit/ entry to a market. This in turn may permanently alter the competitive structures in the market and thus the pass-through relationship (see *Baldwin (1988)*). Further frequently mentioned factors of incomplete exchange rate pass-through are intra firm pricing strategies of multinational corporations or the existence of nontariff barriers in international trade (see *Bhagwati (1988)* and *Branson (1989)*).

Besides these theoretical underpinnings on the pass-through of shocks on prices in general, a more differentiated analysis regarding the effects of shocks on prices at different stages of distribution is of great interest for our analysis. Shocks may affect prices at different stages both directly as well as indirectly via previous price stages. The assumption that shocks are, at least partially, passed-through via previous stages may provide insights as regards both the adjustment speed as well as the size of the pass-through to prices at different stages. Referring to the adjustment speed, in the presence of price stickiness, adjustment lags at different stages of distribution might accumulate. This reasoning tends to imply a decline in the adjustment speed of prices along the distribution chain (compare *Blanchard (1987)*). Further, as regards the size of the pass-through of external shocks two factors have to be considered. First, assuming incomplete pass-through at individual stages, cumulation over different stages basically implies a decline in the pass-through along the distribution chain (compare *Clark (1999)*). Second, the fraction of goods that are affected by external shocks seems to decrease along the distribution chain, pointing to a declining pass-through. For example, the share of tradables, that are likely to be more prone to external shocks than non-tradables (services), tends to decrease in price indices along the distribution chain. The same line of argumentation is used in the exchange rate pass-through literature to explain the observed smaller pass-through to consumer prices compared to import prices. More specifically, these differences are often attributed to local distribution costs (see *Burstein, Eichenbaum and Rebelo (2003)*) or the presumption that import goods partly are intermediate goods that in the production of consumer goods are combined with domestically produced goods (compare *Obstfeld (2001)* and *Bacchetta and van Wincoop (2002)*).

3 The Data and Their Properties

The choice of the proper model depends on the time series properties of the data. Therefore, before turning to the setup of the baseline model, in section 3.1 the data set is presented and in section 3.2 the data properties are discussed.

3.1 The Data Set

The choice of the variables is based on the following considerations. The analysis aims at capturing the effects of changes in oil prices, import prices, and exchange rates on import prices, producer prices, and consumer prices. Thus the corresponding variables have to be included in the model. To avoid double-counting non-oil import prices are considered. Furthermore, to balance the model with respect to the demand side an output gap variable is added in the baseline model. In order to implement long-run restrictions in a later model this variable was replaced by the GDP. Moreover, a short-run interest rate is included in the model to allow for the effects of monetary policy. Neglecting the effects of monetary policy results in the common omitted variables problem. A monetary policy that is concerned with keeping domestic inflation within its target range, is likely to mitigate the effects of exchange rate fluctuations on domestic prices. As a result, the underlying relationship between changes of the exchange rate and domestic prices, that is of vital interest for our analysis, may be masked if monetary policy is excluded from the analysis (see *Parsley and Popper (1998)*).

The analysis is based on quarterly data covering the time period 1970(2) to 2002(2). A detailed account of the data used as well as the data sources is given in Table 7 in Appendix B. In short, the oil price is represented by a crude oil price index denominated in US dollar. The output gap is constructed by applying the Hodrick-Prescott (HP) filter to GDP data.[3] The exchange rate is the effective exchange rate of the Euro. The non-oil import prices are constructed by means of the import deflator.[4] Furthermore, producer prices in manufacturing and the Harmonized Index of Consumer Prices (HICP) are taken into account. Finally, the 3-month interest rate is used to model monetary policy. The time series of the data are depicted in the Figures 22 to 24 in Appendix B.

3.2 The Data Properties

In order to assess the time series properties of the data unit root tests were performed. The results of the Augmented Dickey Fuller (ADF) and the Phillips Perron (PP) tests are summarized in Table 3 in Appendix A.[5] The tests indicate that oil prices (oil_t), GDP (gdp_t), the exchange rate (e_t), non-oil import prices ($impp_t$), producer prices (ppi_t), and nominal interest rates (i_t) are integrated of order one, I(1), while (by construction) the output gap (gap_t) is a stationary series. The test results on the HICP ($hicp_t$) are less clear-cut. Rather they confirm the well-known issue that inflation is a boarderline case between an I(0) and an I(1) process. The same applies for the real interest rate (r_t).

Against the background of a stability oriented monetary policy strategy stationarity of both inflation and the real interest rate seems most plausible. Following these theoretical considerations consistency also requires stationarity of the nominal interest rate. The test

[3] Alternatively to the HP filter output gap two other output gap series based on more sophisticated techniques and the change in GDP were used in the baseline model. The alternative output gap series are constructed by means of unobserved components models. More precisely, the output gap series of the common cycles model and the pseudo-integrated cycles model estimated for the euro area by *Proietti, Musso and Westermann (2002)* were applied. Including the alternative series did not change the results on the impulse response functions that will be presented in section 4.2.2.

[4] The import deflator was chosen as it is the only import price series available over that time period. This decision, however, entails the drawback of capturing both extra and intra euro area imports.

[5] Calculations in this paper are performed with the software packages *EViews*4.0, *Matlab*5.3, and *PcFiml*9.10 (see *Doornik and Hendry (1998)*).

results on the nominal interest rate may then be interpreted as type 2 error. Having in mind the well-known problems associated with unit root tests compared to the strong economic priors this reinterpretation of the test results seems admissible and is thus adopted in the following analysis.[6]

Building on these results Johansen cointegration tests were undertaken to assess the existence of long-run equilibrium relationships among the variables. Based on several lag order selection criteria, Likelihood Ratio (LR) tests of lag order selection and a variety of residual tests a VAR in levels including four lags formed the basis for the cointegration tests. The usual trace statistic indicated two cointegration relationships at the 1 percent significance level and a further one at the 5 percent level, while corrected for small sample it displayed no cointegration (see Table 4 in Appendix A). Thus, taking into account the two stationary variables in the system, only weak evidence for one cointegration relationship remains. We therefore refrained from including a cointegration term in the model. Hence, in the next section a VAR model in first differences of the variables, where necessary, is estimated.[7]

4 The Baseline Model

This section comprises two parts. The first part of the section refers to the setup and the identification of the baseline model. In the second part the empirical results on the pass-through in the euro area derived from this model are presented.

4.1 Setup and Identification of the Baseline Model

In this section the basic modelling framework used to estimate the pass-through of external shocks to domestic inflation in the euro area is derived. Referring to the discussion above a first difference VAR model was chosen for our analysis. Identification of the structural

[6]Comparisons of the estimation results of the model presented in section 4 to those of models based on different assumptions on the time series properties showed that the results are extremely robust across different model specifications.

[7]Estimation of an error correction model including an unidentified cointegration relationship yielded very similar results to the chosen specification.

shocks of this model in the baseline case is achieved by applying a Choleski decomposition. The Choleski decomposition encompasses the decomposition of the variance covariance matrix Ω of the reduced form residuals in a lower triangular matrix S and an upper triangular matrix S'. Thus the $n(n-1)/2$ economic restrictions, necessary to identify the structural model, are imposed as zero restrictions on the matrix S, that links the reduced form and the structural residuals. Economically, these restrictions imply that some of the structural shocks do not have a contemporaneous impact on some of the variables. Economic interpretation is attached to this model through the selected ordering of the variables, as the ordering indicates which shocks are not allowed to contemporaneously affect which variables.

Referring to the variables of interest for our analysis and taking into account their unit root properties, the variables included in the model are the first differences of the logs of oil prices ($\triangle oil_t$), the exchange rate ($\triangle e_t$), non-oil import prices ($\triangle impp_t$), producer prices ($\triangle ppi_t$), and the HICP ($\triangle hicp_t$), and the levels of the output gap and the interest rate. Different orderings of these variables seem reasonable. In the baseline model we decided in favour of the ordering of the variables indicated by the vector of endogenous variables $x_t = (\triangle oil_t, i_t, gap_t, \triangle e_t, \triangle impp_t, \triangle ppi_t, \triangle hicp_t)'$. Using this ordering in the Choleski decomposition the relationship between the reduced form residuals, e_t, and the structural shocks, ϵ_t, of the model can be written as in equation (1).

$$\begin{pmatrix} e_t^{oil} \\ e_t^{i} \\ e_t^{gap} \\ e_t^{e} \\ e_t^{impp} \\ e_t^{ppi} \\ e_t^{hicp} \end{pmatrix} = \begin{pmatrix} S_{11} & 0 & 0 & 0 & 0 & 0 & 0 \\ S_{21} & S_{22} & 0 & 0 & 0 & 0 & 0 \\ S_{31} & S_{32} & S_{33} & 0 & 0 & 0 & 0 \\ S_{41} & S_{42} & S_{43} & S_{44} & 0 & 0 & 0 \\ S_{51} & S_{52} & S_{53} & S_{54} & S_{55} & 0 & 0 \\ S_{61} & S_{62} & S_{63} & S_{64} & S_{65} & S_{66} & 0 \\ S_{71} & S_{72} & S_{73} & S_{74} & S_{75} & S_{76} & S_{77} \end{pmatrix} \begin{pmatrix} \epsilon_t^{oil} \\ \epsilon_t^{i} \\ \epsilon_t^{gap} \\ \epsilon_t^{e} \\ \epsilon_t^{impp} \\ \epsilon_t^{ppi} \\ \epsilon_t^{hicp} \end{pmatrix} \tag{1}$$

Ordering the change in oil prices first seemed most plausible as this implies that oil price shocks, ϵ_t^{oil}, may affect the reduced form residuals of all equations and thus all variables in the system contemporaneously, while, in contrast, the reduced form residuals of oil prices, e_t^{oil}, and thus the change in oil prices are not affected contemporaneously by any of the other shocks (compare equation(1)). Monetary policy represented by its instrument, the interest rate, was ordered next. Due to the lagged availability of GDP data, it seemed more reasonable to allow for a contemporaneous impact of monetary policy shocks, ϵ_t^i, on the output gap than vice versa. In addition, it appears highly plausible to admit a contemporaneous effect of monetary policy shocks on the exchange rate. This ordering implies further that monetary policy does not react to realized inflation but to expected inflation and may thus affect prices at different stages contemporaneously. Next, the output gap is ordered prior to the exchange rate, which allows the exchange rate to respond contemporaneously to, among others, demand shocks ϵ_t^{gap}. Finally, the price variables are ordered according to the distribution chain ($\triangle impp_t$, $\triangle ppi_t$, $\triangle hicp_t$). All price variables are affected contemporaneously by the four previous shocks, the price shocks on previous price stages, and their own. The price shock on a stage is the part of inflation at that stage, that can neither be explained by the available information in $t-1$ on inflation at that stage (indicated by the lags of the endogenous variables), nor by the contemporaneous shocks to the variables at previous stages. Alternative plausible orderings of the variables to the one discussed here will be analyzed in section 5.2.1.

4.2 The Empirical Results

In this section the empirical results derived from the baseline model are presented and discussed. The setup of the baseline model was derived in the previous section. The exact specification of this VAR model is described in section 4.2.1. Using impulse response functions in section 4.2.2 the size and the speed of the pass-through of oil price, non-oil import price, and exchange rate shocks to non-oil import prices, producer prices and the HICP are analyzed. In section 4.2.3 the relative importance of external shocks for fluctuations in the price indices is investigated by applying variance decompositions. Finally, in section 4.2.4 the contribution of external shocks, that occurred since the start of the EMU in January 1999, to inflation at different price stages is examined using historical decompositions.

4.2.1 Specification of the VAR Model

To determine the lag order of the VAR model several order selection criteria as well as LR tests of parameter reduction were performed. While the Akaike Information Criterion (AIC) indicated two lags, the Hannan-Quinn (HQ) and the Schwarz Criterion (SC) reported one lag and the LR tests pointed towards a reduction from four to three lags yet not further (see Table 5 and Table 6 in the Appendix A). Analyzing a number of specification tests we decided to rely on the LR test results. The VAR model therefore was estimated with a constant and three lags. Taking into account lags and differenced variables the estimation sample covers the time period from 1971(2) to 2002(2).

4.2.2 Impulse Response Functions

In this section the impulse responses of the different price indices to external shocks are reported and analyzed along the distribution chain. Thus, first the responses of import prices to the different external shocks are discussed. Thereafter we turn to the responses of producer prices and finally to those of the HICP. The (accumulated) impulse responses are displayed over a time horizon of twelve quarters. This is the most relevant time period for our analysis and the effects thereafter in most cases are not significant. All shocks are standardized to one-percent shocks. As a result, the vertical axis in the Figures displaying the impulse response functions indicates the approximate percentage point change in the respective price index due to a one percent shock in the respective variable or, equivalently, the percentage of the pass-through.[8]

Impulse Responses of Non-Oil Import Prices The responses of non-oil import prices in the euro area to oil price and exchange rate shocks are displayed in Figure 1. As regards the response of non-oil import prices to a one percent increase in US dollar oil prices the impact effect surprisingly is slightly negative. As of the second quarter the effect is clearly positive. The higher input prices for oil are passed-through to non-oil import prices. The pass-through amounts to about eight percent after one year. After

[8] The two standard error bands of the impulse response functions are obtained by Monte Carlo simulations based on normal draws from the distribution of the reduced-form VAR model.

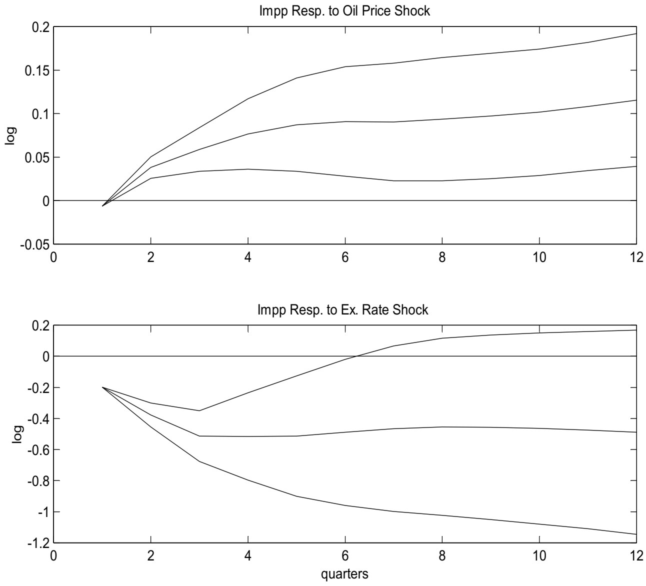

Figure 1: Impulse Responses of Import Prices

three years it accumulates to twelve percent. The response of non-oil import prices to a one percent appreciation of the Euro is quite strong and passes-through very quickly. Already the impact effect amounts to 20 percent. The total effect of about 50 percent is passed-through within only three quarters. These results seem to be in line with the 50 to 70 percent pass-through found by *Anderton (2003)*.[9]

As was indicated in section 2 the size of the pass-through of (external) shocks on prices may depend on a multitude of economic factors. Correspondingly, the analysis of the economic factors that determine the degree of the pass-through and also differences in the size of the pass-through of different shocks is quite difficult. This venture is even more ambitious as regards the pass-through on aggregated price indices. However, in analogy

[9]In contrast to the non-oil import deflator used in this paper the findings of *Anderton (2003)* refer to extra-euro area manufacturing import prices. Abstracting from differences in the results that may come from factors like different applied methodologies or different sample periods, the differences in the choice of the data may affect the results in two ways. On the one hand, as our import deflator opposed to that of *Anderton (2003)* includes both extra and intra euro area imports and assuming that the pass-through to intra import prices is lower than that to extra import prices the response of our import deflator to an exchange rate shock should be lower than that of *Anderton (2003)*. On the other hand, while our import deflator is adjusted for the impact of oil prices, import prices in manufacturing additionally exclude the impact of commodities. Commodities are known to show an extraordinarily large exchange rate pass-through. Taken individually this difference in the data would thus imply a higher exchange rate pass-through to our import deflator compared to that of *Anderton (2003)*.

to the discussion on the differences in the size of the pass-through along the distribution chain and with reference to *Taylor (2000)*, three factors may help to explain differences in the size of the pass-through of different shocks on price indices. First, the size of the pass-through depends on the share of prices in the price index that are affected by the respective shock. Second, the number of stages that have to be passed plays an important role for the size of the effect, as the pass-through at most stages seems to be incomplete. Third, to follow *Taylor (2000)* differences in the size of the pass-through may be due to different degrees of persistence of the shocks. Against this background, the most obvious explanation for the much larger impact of an exchange rate shock on non-oil import prices compared to an oil price shock is that the exchange rate shock affects all non-oil import prices directly, while the oil price shock has only an indirect impact on that fraction of non-oil import goods that use oil as an input factor.

The number of stages that a shock has to pass may also be seen as a main determinant of the speed of the pass-through as each stage usually seems to contain a time lag. A comparison between the adjustment speed of non-oil import prices to oil and exchange rate shocks is provided in Figure 2. The two lines give the percentages of the total pass-through of oil and exchange rate shocks on non-oil import prices that have materialized after different time horizons respectively.[10] The much faster adjustment speed of exchange rate shocks may be attributed to the direct impact of these shocks on non-oil import prices in contrast to the chain of production that has to be passed by oil price shocks.

Impulse Responses of Producer Prices The responses of producer prices in manufacturing to shocks in oil prices, the Euro exchange rate, and non-oil import prices are displayed in Figure 3. As regards the response of producer prices in manufacturing to a one percent increase in US dollar oil prices, the impact effect of the pass-through is two percent, which increases to five percent after one year, and accumulates to seven percent after three years. The one percent appreciation of the Euro exchange rate is passed-through on producer prices by ten percent after one quarter, by 28 percent after

[10]The total effect was defined as the pass-through after three years. Choosing a later benchmark horizon did not seem reasonable as most effects are estimated imprecisely over later horizons.

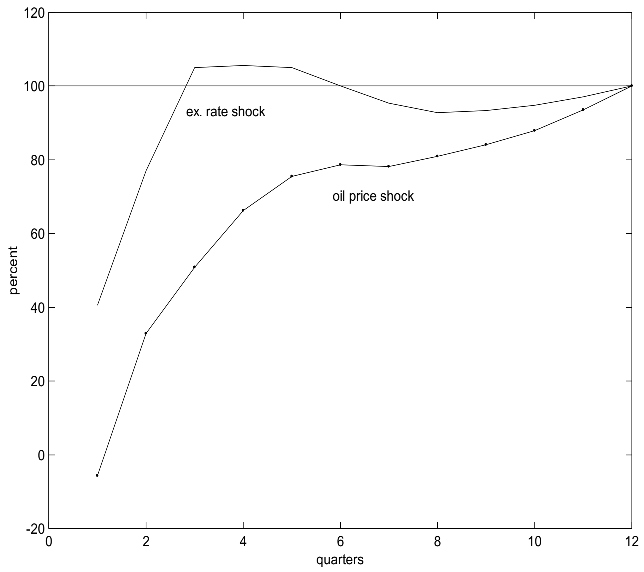

Figure 2: Comparison of the Adjustment Speed of Import Prices to Oil Price and Exchange Rate Shocks

one year, and amounts to about 30 percent after three years. The impact of a one percent increase in non-oil import prices on producer prices is extremely large. In the first quarter the pass-through amounts to 22 percent, increasing to 61 percent after four quarters. The pass-through after three years is however already imprecisely estimated.

Summarizing the results on the size of the pass-through on producer prices, a non-oil import price shock has a much larger impact than a corresponding exchange rate shock, which in turn has a much larger impact than a corresponding oil price shock. Again, the fraction of prices in the price index that is affected by the respective shock and the number of pass-through stages may be important determinants of these differences. Moreover, in line with the argumentation of *Taylor (2000)* the observed higher degree of the pass-through of non-oil import price shocks compared to exchange rate and oil price shocks may also be due to a higher perceived persistence of the non-oil import price shocks. While exchange rate and oil price shocks are known to be pretty volatile, non-oil import price shocks are likely to contain the more persistent external sources of variation

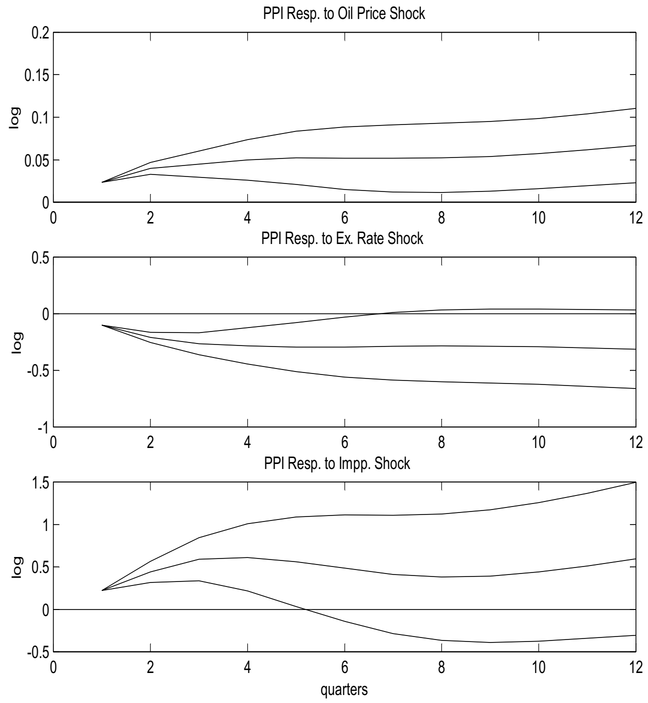

Figure 3: Impulse Responses of Producer Prices

(including, e.g., the impact of the euro area's trading partners underlying inflation).

A comparison of the adjustment speed of producer prices to the different shocks is provided in Figure 4. Again, the number of pass-through stages seems to be an important determinant of the adjustment speed. Thus the non-oil import price shock shows the highest adjustment speed. The whole effect is passed-through within three quarters.[11] As in the case of non-oil import prices, the adjustment speed of producer prices to an exchange rate shock is faster than to an US dollar oil price shock.

Impulse Responses of the HICP The responses of the HICP to an oil price, an exchange rate, and a non-oil import price shock are depicted in Figure 5. The one percent

[11]The decline after the fourth quarter should not be taken too seriously, as most of this part of the pass-through is already insignificantly estimated.

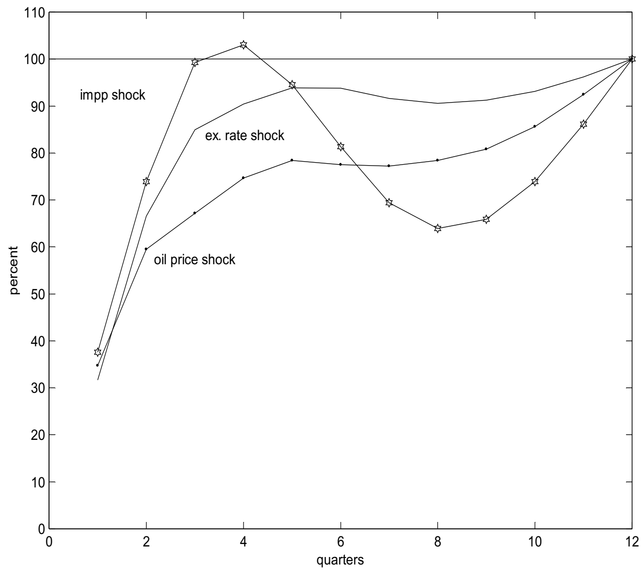

Figure 4: Comparison of the Adjustment Speed of Producer Prices to Oil Price, Exchange Rate and Import Price Shocks

increase in US dollar oil prices is passed-through on the HICP in the first quarter by 0.5 percent, after four quarters by roughly two percent, and after three years by about five percent. The pass-through of a one percent appreciation of the Euro on the HICP in the first quarter is roughly 2.5 percent. It increases to eight percent after one year and to about 16 percent after three years. Thus our estimates of the exchange rate pass-through on the HICP are twice as large as those reported by *Hüfner and Schröder (2002)*. Again, the pass-through of a non-oil import price shock is quite large. The shock is passed-through to the HICP by four percent after one quarter, by 17 percent after one year, and by 31 percent after three years.

The ordering of the shocks as regards the size of their impact on the HICP is the same as for non-oil import prices and producer prices. A non-oil import price shock has the largest impact, followed by the exchange rate shock and the oil price shock. A comparison of the adjustment speed of the HICP to the different shocks is given in Figure 6. Again, the same ordering as before emerges. The pass-through is fastest for the non-oil import

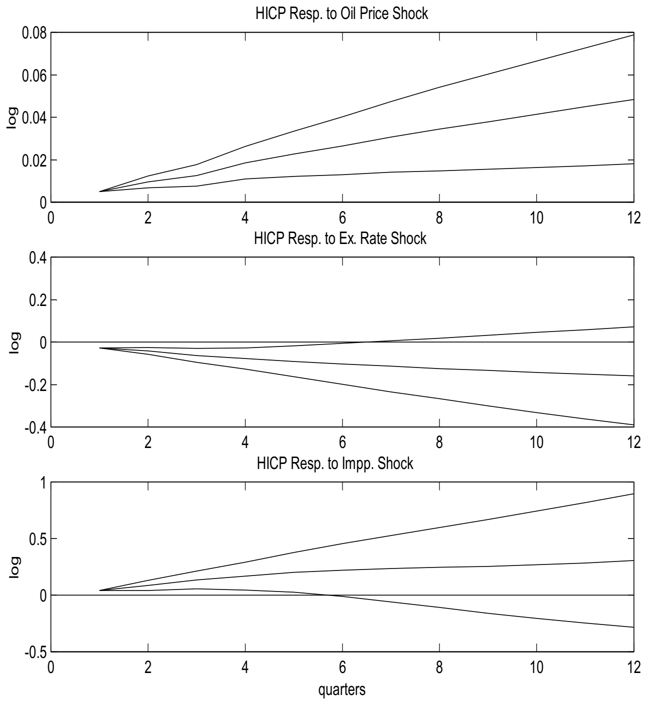

Figure 5: Impulse Responses of the HICP

price shock, followed by the exchange rate shock, and finally the US dollar oil price shock.

Closing the discussion on the degree and dynamics of the pass-through of external shocks on inflation, a comparison of the size and the speed of the pass-through of the shocks along the distribution chain, i.e. across the different price indices, is in order. As regards the size, the pass-through of all shocks is largest on non-oil import prices, second are producer prices, and smallest for the HICP, i.e. the size of the pass-through decreases along the distribution chain. As was discussed in section 2 this decline may be due to a smaller fraction of goods affected by the respective shocks in the price indices at later stages of the distribution chain and, furthermore, because of a cumulation over a larger number of incomplete pass-through stages. The cumulation over a larger number of small lags is also likely to be responsible for the observed decline in the adjustment speed along

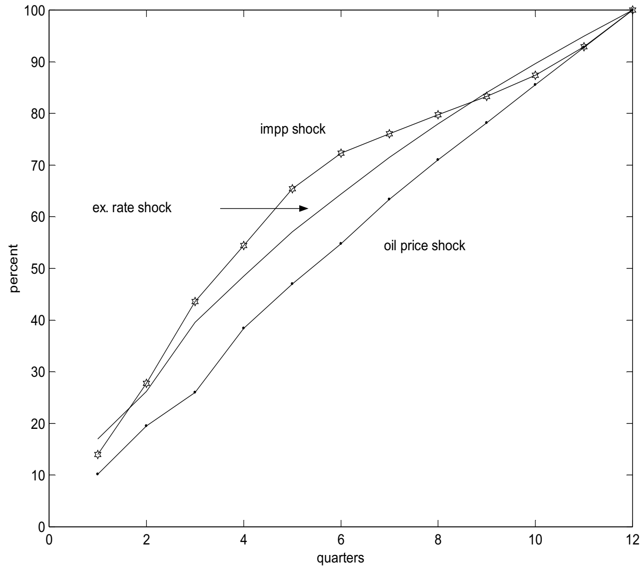

Figure 6: Comparison of the Adjustment Speed of the HICP to Oil Price, Exchange Rate and Import Price Shocks

the distribution chain. That is the adjustment speed to a shock is fastest for non-oil import prices, followed by producer prices and slowest for the HICP.

4.2.3 Variance Decompositions

Additional insights into the impact of external shocks on the different price indices to those obtained by the impulse responses functions may be gained from variance decompositions. While impulse response functions provide information on the size and speed of the pass-through, they give no information on the importance of the respective shocks for the variance of the price indices. By contrast, variance decompositions indicate the percentage contribution of the different shocks to the variance of the k-step ahead forecast errors of the variables. Hence, the relative importance of the different external shocks for the development of the price indices since the 1970s may be assessed.

Figure 7 summarizes the results on the variance decompositions of non-oil import prices, producer prices, and the HICP over a forecast horizon of twelve quarters. For

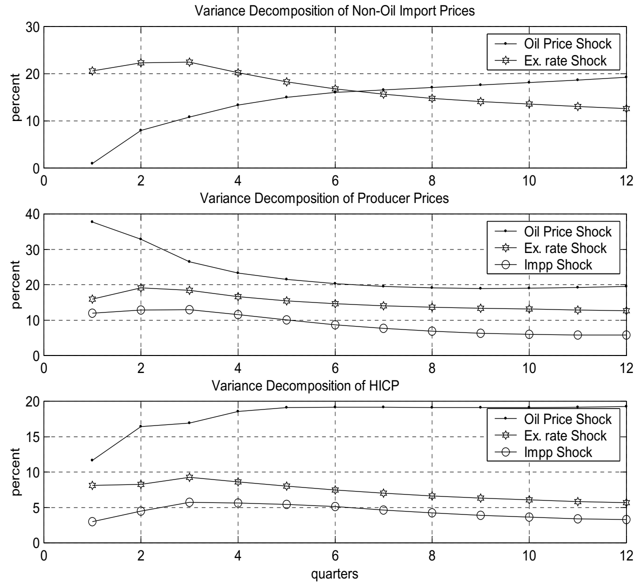

Figure 7: Variance Decompositions

the sake of clearness only the contributions of external shocks, i.e. of oil price shocks, exchange rate shocks, and non-oil import price shocks, are reported.

With regard to the variance of non-oil import prices, exchange rate shocks are an important determinant. Initially they account for about twenty percent of the variance. This share declines to about twelve percent as the forecast horizon increases. In contrast, the impact of oil price shocks initially is modest, but increases over the forecast horizon to almost twenty percent. This development reflects the fact that it takes time until changes in the input factor oil are reflected in the prices of non-oil import goods.

As regards the variance decomposition of producer prices, the most important external shocks are oil price shocks, which contribute between 20 to 40 percent to the variance of producer prices over different forecast horizons. Between five to twenty percent of the variance are accounted for by exchange rate and import price shocks respectively.

As for the variance decomposition of the HICP, again oil prices explain the largest fraction of the variance of the HICP regarding the external shocks. The initial impact is twelve percent which increases with the forecast horizon to about twenty percent. The impact of exchange rate and non-oil import price shocks is rather modest. They account for about three to ten percent of the variance of the HICP respectively.

To sum up, external factors explain a large fraction of the variance of all price indices. Among the external factors oil price shocks are most important. Except for oil price shocks, the impact of external shocks on the variance of the price indices decreases along the distribution chain.

4.2.4 Historical Decompositions

The impulse responses and variance decompositions analyzed in the previous sections are based on shocks of standardized size. These kinds of analyses enable a comparison of the strength of the impact of different shocks on the variables. The actual impact of the shocks on the variables, however, also depends on the size and number of shocks that occur. Historical decompositions take care of both the strength of the impact of the respective shocks and the actual number and size of these shocks. The impact of a shock is then analyzed by allowing the shock of interest in the model, while the others are set to zero.

In this section historical decompositions are used to analyze the impact of external shocks, that occurred since the start of the EMU, on the development of the different price indices during that time period. As in *McCarthy (2000)* the average annualized contribution of the respective shocks over the time period of interest is computed. This is done in the following way: First, the actual average annualized development of the three price indices over the period 1999(1) to 2002(2) is calculated (see column two in Table 1). Second, the corresponding numbers are calculated assuming that no further shocks occurred since the start of the EMU (see column three). The difference between the actual development and the projected development is denoted as a projection error (see column four). The projection error gives the average annualized contribution of all shocks that occurred over that time period on inflation during that period. It provides an indication of how unusual the development of the price indices was during that period. Third, the average annualized development of the three price indices is derived under the

Table 1: Historical Decompositions[1]

Variables	Actual[2]	Projection[3]	Proj. Error[4]	Contribution of Shocks[5]						
				oil	*i*	*gap*	*e*	*impp*	*ppi*	*hicp*
$\triangle impp$	1.73	1.82	-0.09	1.26	-1.10	0.14	1.44	-0.98	0.20	-1.06
$\triangle ppi$	2.22	1.81	0.41	0.74	-0.73	-0.06	0.94	-0.18	0.32	-0.62
$\triangle hicp$	2.19	2.11	0.08	0.78	-0.51	0.05	0.49	-0.18	0.14	-0.68

[1] All numbers are annualized percentage changes of the respective variable over the period 1999(1) to 2002(2).
[2] Actual development of the respective variable over the period 1999(1) to 2002(2).
[3] Projected development of the respective variable, based on the data until 1998(4) and the assumption of no further shocks after 1998(4).
[4] The projection error is defined as the difference between the actual development and the projected development.
[5] The contribution of the shock is defined as the difference between the projection including the respective shock and the projection excluding all shocks.
Due to rounding errors the contributions do not add up exactly to the projection error.

assumption that only the shocks of interest occurred respectively. The contribution of the respective shocks is then derived as the difference between the projection including the respective shock and the projection excluding all shocks (see columns five to eleven).

Care has to be taken in the interpretation of the contribution of shocks. The contribution indicates how much larger/smaller inflation would be due to that shock compared to the projection of price developments based on all shocks that occurred in the past. It does not by itself indicate that this kind of shock contributed more or less to inflation than in the past. That is a large positive/negative contribution is not by itself an indication of a larger positive/negative shock to one variable during that period than in previous periods, although it might be.

Starting with the analysis of non-oil import price inflation, on average actual non-oil import price inflation was slightly below its projection since the start of the EMU (see Table 1). In sum the shocks that occurred since 1999(1) contributed to lower non-oil import price inflation by 0.09 percentage points. External shocks (*oil*,*e*,*impp*) in sum however were a strong positive contributor to non-oil import price inflation. Taken together these shocks accounted for about 1.7 percentage points of non-oil import price inflation. Taken individually external shocks affected non-oil import price inflation quite differently. While oil price shocks and exchange rate shocks were strong positive contributors to non-oil import price inflation, the impact of non-oil import price shocks was clearly negative. As regards the other shocks, the strong disinflationary impact of HICP shocks and interest rate shocks is most worth mentioning.

Actual producer price inflation was 0.41 percentage points above its projection on average during the EMU period. As in the case of non-oil import price inflation, external factors were strong positive contributors to producer price inflation (1.5 percentage points). Oil price shocks and exchange rate shocks contributed strongly to increase producer price inflation, while non-oil import price shocks again had a disinflationary impact on producer prices. Also, HICP and interest rate shocks contributed strongly to lower producer price inflation.

Actual HICP inflation on average over the EMU period was close to its projection. In sum, the shocks that occurred during the EMU period increased HICP inflation by just 0.08 percentage points. Taken separately however quite substantial contributors to HICP inflation were identified. External factors were large positive contributors to HICP inflation. They accounted for about one percentage point of HICP inflation. Oil price shocks contributed 0.78 percentage points, exchange rate shocks 0.49 percentage points and the impact of non-oil import price shocks again was negative (-0.18 percentage points). Despite these strong inflationary impacts of external shocks HICP inflation was close to its projection, as the inflationary impacts were counter-balanced by strong disinflationary impacts of HICP and interest rate shocks.

To sum up, external factors in sum had large inflationary impacts on all price indices in the euro area over the EMU period. Their impact declined slightly over the distribution chain. Oil price shocks and exchange rate shocks were large positive contributors to all price indices. From the external side, these impacts were counterbalanced partly by a disinflationary impact of non-oil import price shocks. Large disinflationary HICP and interest rate shocks acted as strong counterbalance to these external inflationary tendencies.

Comparing these results to the price shocks that could be observed since the start of the EMU most of the results seem to be quite plausible. Since 1999 substantial upward shocks to oil prices were accompanied by the large depreciation of the exchange rate of the Euro. Furthermore, the euro area was hit by both upward and downward shocks to non-oil import prices. These shocks were followed by large upward shocks to the prices of unprocessed food which originated from animal diseases like BSE and the food and mouth disease and bad weather conditions.[12] The large inflationary contributions of oil price and exchange rate shocks indicated by the model clearly correspond to these developments. The opposed developments of non-oil import prices shocks are identified by the model as negative contributors to inflation. Surprising is, however, that despite the strong inflationary shocks to unprocessed food prices, which must be subsumed to HICP shocks, these shocks are identified by the model as strong disinflationary contributors.

5 Robustness Analysis

The results achieved in the previous section may be specific to the selected time period or the setup of the model. In this section we therefore investigate the robustness of the results as regards these two points. In section 5.1 we examine the robustness of the pass-through of external shocks to inflation in the euro area over time. The robustness of the results across a number of different identification schemes is explored in section 5.2.

5.1 Robustness Over Time

The robustness of the pass-though of external shocks on euro area inflation over time is investigated by estimating the model over different time periods. More precisely, the analysis is conduced for the sample periods 1971 to 1984 and 1985 to 2002. It seems interesting to see whether the evidence of a decline in the exchange rate pass-through that was reported by *Gagnon and Ihrig (2002)* for a number of industrialized countries, among them also countries participating in the EMU, shows up also for the euro area as a whole. In line with the argumentation of *Taylor (2000)*, *Gagnon and Ihrig (2002)* attributed this decline in the pass-through to an increased emphasis of monetary policy

[12]See *European Central Bank (2002).*

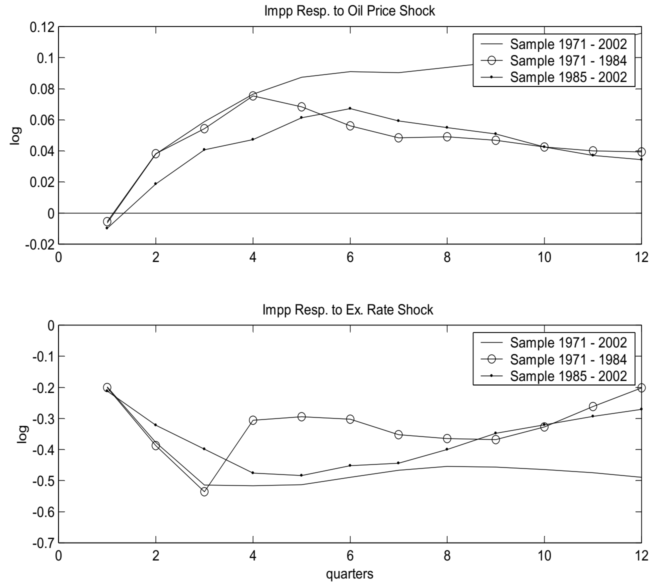

Figure 8: Recursive Impulse Responses of Import Prices

on stabilizing inflation.

Figures 8 to 10 provide a comparison of the results on the impulse response functions of non-oil import prices, producer prices and the HICP for the different time periods. For ease of comparison the impulse response functions for the whole sample period are repeated. Probably due to the rather short sub-samples the impulse responses referring to the sub-samples were significant only for shorter forecast horizons compared to those of the whole sample. Comparisons should thus refer only to shorter forecast horizons.

The overall picture that emerges is that the size and speed of the pass-through seem to be stable over time. As regards the impulse responses of non-oil import prices in Figure 8 the size of the responses might have declined slightly in the latter sample period. The deviations, however, are rather small and probably insignificant. The impulse responses of producer prices that refer to the whole sample and the sample starting in the mid-80s are very similar (compare Figure 9). Those referring to the sample starting in the 70s became insignificant at the horizons where they deviated from the others. The impulse responses of the HICP were similar over shorter horizons (see Figure 10). One exception

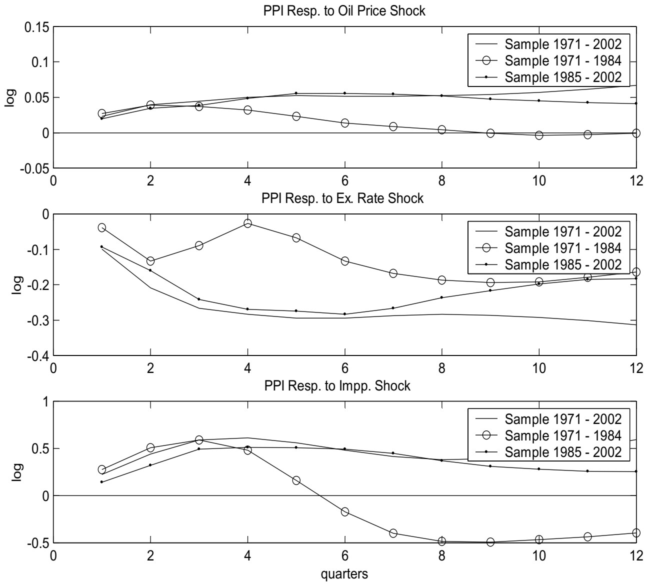

Figure 9: Recursive Impulse Responses of Producer Prices

is the impulse response to a non-oil import price shock for the sample starting in the 70s. This response was however insignificant from the beginning.

Thus, in contrast to the findings of *Gagnon and Ihrig (2002)* as regards a number of countries, our results provide no strong evidence of a decline in the exchange rate pass-through to prices in the euro area over the estimated sample periods. However, as the estimates are averages over the respective sample periods from these results no conclusions may be drawn as regards a potential change in the pass-through in the euro area in recent years.

The variance decompositions for the samples starting in the 70s and the mid-80s are displayed in the Figures 11 and 12. From the comparison of these Figures it is obvious that the relative importance of external shocks as regards fluctuations of prices has clearly increased. This result applies not only to external shocks in sum but also to individual external shocks and holds for all price indices. A potential explanation for this result might be a stronger focus of monetary policy on stabilizing the domestic sources of variation in prices in recent years. Similar results on consumer prices for a number of industrialized

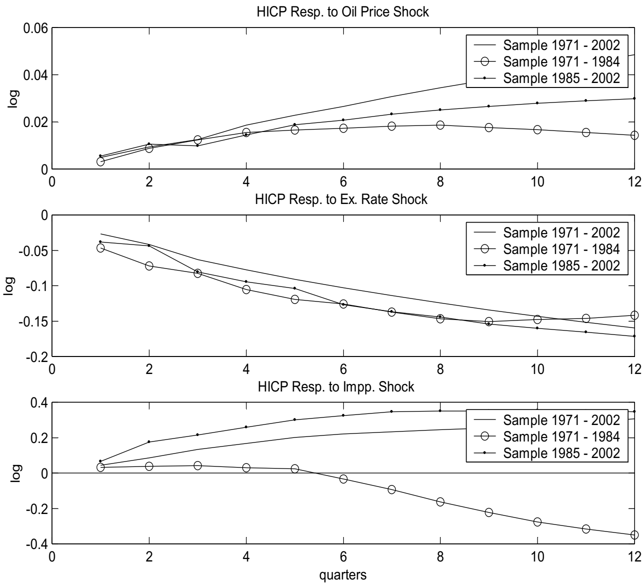

Figure 10: Recursive Impulse Responses of the HICP

countries were reported by *McCarthy (2000)*.

Finally, also the robustness of the results derived from the historical decompositions is analyzed. To that aim the impact of external shocks on euro area inflation in the period since the start of the EMU is computed based on the sample period starting in 1985. To facilitate the comparison with the results for the whole sample the results for both sample periods are reported in Table 2. Based on the sample starting in 1985 the projection errors for all price indices were positive and quite large indicating that overall the shocks that occurred since the start of the EMU had a quite strong inflationary impact on prices. In sum, external shocks remained strong positive contributors to all price indices over the EMU period. The size of these contributions however was much smaller than for the whole sample period. Still, oil price shocks were substantial positive contributors to inflation in the EMU. Surprisingly, exchange rate shocks basically switched from positive to negative contributors to inflation. In contrast, non-oil import price shocks changed from negative to positive contributors to inflation in the latter sample.

To summarize the results, while the size and speed of the pass-through was quite

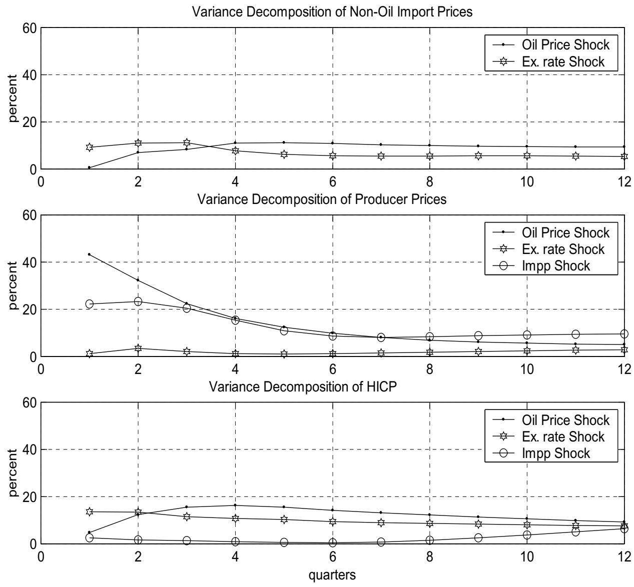

Figure 11: Variance Decompositions for the Sample Period 1971 to 1984

robust over time, the impact of external shocks on the different price indices seems to have increased. The estimated contributions of shocks that occurred since 1999 to inflation over the period since the start of the EMU varied substantially across the different samples. For the later sample still, in sum, external shocks were strong positive contributors to inflation, however to a smaller extent than for the longer sample period.

5.2 Robustness Over Different Identification Schemes

It is a well-known issue that the results derived from VAR models may strongly depend on the underlying identification scheme. In this section therefore the robustness of the results derived from the baseline model is explored across different identification schemes. This is done in two ways. First, the robustness of the results across alternative plausible orderings of the variables in the Choleski decomposition is examined. Second, the robustness as regards an identification scheme that includes both short-run and long-run restrictions is investigated. These robustness tests are restrained to the analysis of the size and the speed of the pass-through.

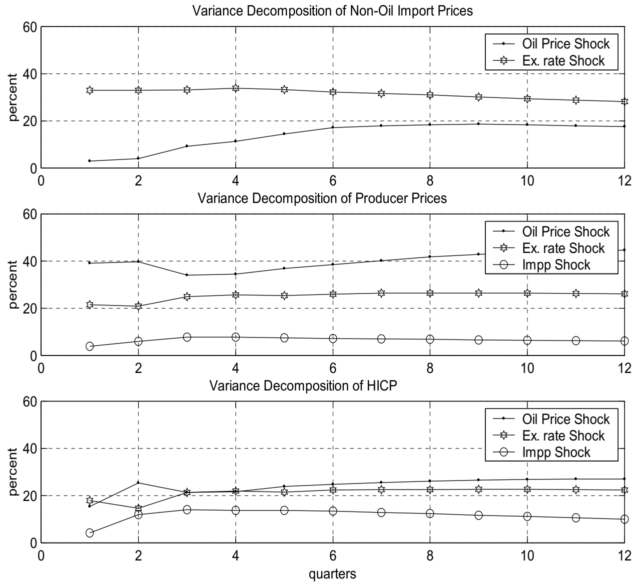

Figure 12: Variance Decompositions for the Sample Period 1985 to 2002

5.2.1 Robustness Across Different Orderings of the Variables

Economic theory does not impose one particular ordering on the contemporaneous relationship between the variables of interest. Rather, several economically plausible orderings of the variables are conceivable. As a result, in this section we investigate whether the results achieved with the baseline model are robust across alternative plausible orderings of the variables in the Choleski decomposition. Recalling the ordering of the variables in the baseline model, oil prices were ordered first, followed by the monetary policy instrument, the output gap and the exchange rate. The different price variables along the distribution chain were ordered last, i.e. $x_t = (\triangle oil_t, i_t, gap_t, \triangle e_t, \triangle impp_t, \triangle ppi_t, \triangle hicp_t)'$.

One plausible change in the ordering of the variables concerns the output gap variable. Different from the baseline model, it seems also reasonable to allow for a contemporaneous impact of all external variables (oil prices, exchange rate, non-oil import prices) on the output gap. Thus compared to the baseline model the output gap might be deferred after the import price variable, the order of the other variables being the same, i.e. $x_t = (\triangle oil_t, i_t, \triangle e_t, \triangle impp_t, gap_t, \triangle ppi_t, \triangle hicp_t)'$.

Table 2: Historical Decompositions[1]

Variables	Actual[2]	Projection[3]	Proj. Error[4]	Contribution of Shocks[5]						
				oil	*i*	*gap*	*e*	*impp*	*ppi*	*hicp*
Sample period 1971 - 2002										
$\triangle impp$	1.73	1.82	-0.09	1.26	-1.10	0.14	1.44	-0.98	0.20	-1.06
$\triangle ppi$	2.22	1.81	0.41	0.74	-0.73	-0.06	0.94	-0.18	0.32	-0.62
$\triangle hicp$	2.19	2.11	0.08	0.78	-0.51	0.05	0.49	-0.18	0.14	-0.68
Sample period 1985 - 2002										
$\triangle impp$	1.73	1.42	0.31	0.09	-0.07	0.16	-0.14	0.72	-0.29	-0.23
$\triangle ppi$	2.22	1.59	0.63	0.37	-0.05	-0.07	-0.11	0.24	0.30	-0.08
$\triangle hicp$	2.19	1.61	0.58	0.35	-0.26	0.13	0.03	0.07	0.14	0.08

[1] All numbers are annualized percentage changes of the respective variable over the period 1999(1) to 2002(2).
[2] Actual development of the respective variable over the period 1999(1) to 2002(2).
[3] Projected development of the respective variable, based on the data until 1998(4) and the assumption of no further shocks after 1998(4).
[4] The projection error is defined as the difference between the actual development and the projected development.
[5] The contribution of the shock is defined as the difference between the projection including the respective shock and the projection excluding all shocks.
Due to rounding errors the contributions do not add up exactly to the projection error.

A further potential change in the ordering of the variables relates to the monetary policy variable. It seems also reasonable to order monetary policy last as was suggested by *McCarthy (2000)*. This implies that the central bank reaction function allows for a contemporaneous reaction of monetary policy to all shocks in the model, while monetary policy actions affect all variables with a time lag of at least one quarter. The endogenous variables are then ordered as indicated in the vector $x_t = (\triangle oil_t, gap_t, \triangle e_t, \triangle impp_t, \triangle ppi_t, \triangle hicp_t, i_t)'$.

Finally, as a third alternative, both of the above mentioned changes in the ordering of the variables may be taken into account at the same time, i.e. $x_t = (\triangle oil_t, \triangle e_t, \triangle impp_t, gap_t, \triangle ppi_t, \triangle hicp_t, i_t)'$.

Figures 13 to 15 provide a comparison of the impulse response functions of the different price indices to external shocks across the different orderings of the variables discussed above. For the sake of comparability the impulse responses of the baseline model are replicated in these Figures. The alternative models are numbered in order of description

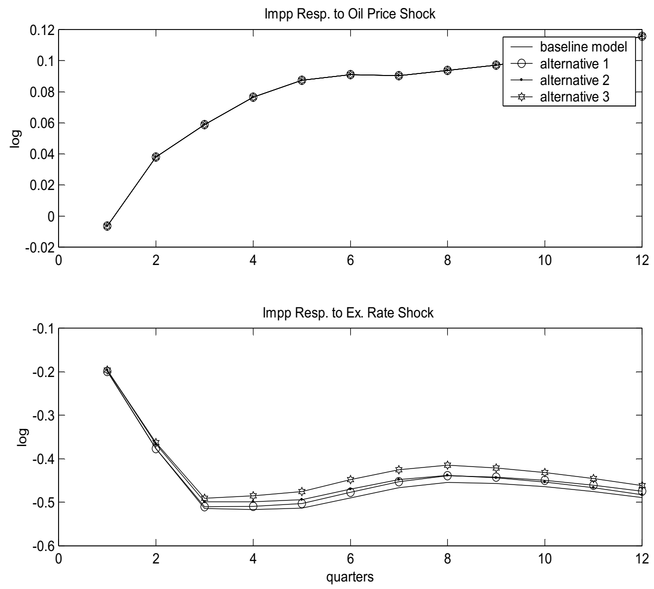

Figure 13: Impulse Responses of Import Prices Across Different Orderings

above. As can easily be seen the impulse responses of all price indices are extremely robust across the different orderings. None of the changes seems to be of significant size. As regards the absence of changes in the impulse responses to oil price shocks, it has to be noted though that this result is by construction as the role of oil price shocks is unchanged in the different identification schemes. However, moving down the output gap and interest rate variables, respectively, behind the exchange rate and non-oil import prices basically allows the exchange rate and non-oil import price shocks to affect the system and thus prices in a different way. Among the tiny changes that can be observed for these shocks the most obvious difference occurs as regards the responses of producer prices and the HICP to non-oil import price shocks. Allowing for a contemporaneous effect of interest rate shocks on exchange rates and non-oil import prices seems to slightly diminish the impact of these shocks on the two price indices.

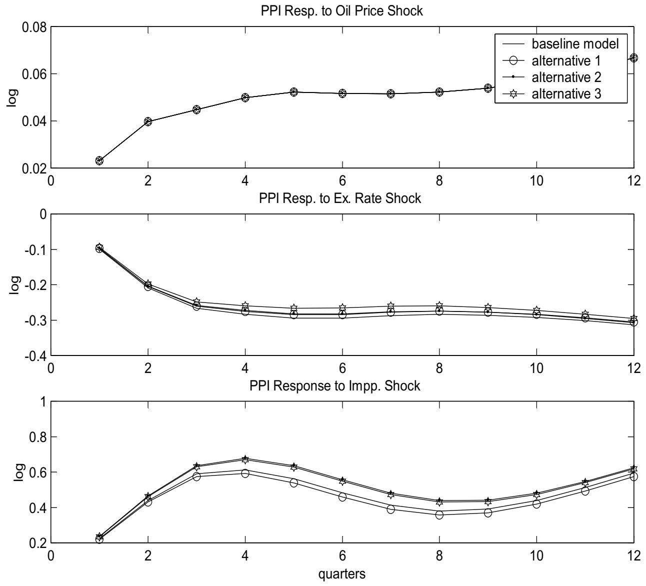

Figure 14: Impulse Responses of Producer Prices Across Different Orderings

5.2.2 Robustness As Regards an Identification Scheme that Includes Both Short and Long-Run Restrictions

As a further robustness analysis in this section we develop an alternative structural identification scheme which employs a mixture of short and long-run[13] identifying restrictions. Such identification schemes were put forward by *Galí (1992)*, *Gerlach and Smets (1995)* and *Mélitz and Weber (1997)* and were recently applied to the euro area for instance by *Monticelli and Tristani (1999)* and *Peersman and Smets (2001).* Like our model these models include, e.g., the more standard macroeconomic variables like GDP, consumer price inflation and interest rates. However, none of them allows for the distribution chain of pricing.

In order to implement long-run restrictions as regards the level of output, in this model the output gap variable is replaced by the change in GDP, i.e. $\triangle y_t$. Identification of our VAR model for $x_t = (\triangle oil_t, i_t, \triangle y_t, \triangle e_t, \triangle impp_t, \triangle ppi_t, \triangle hicp_t)'$ is then achieved in the

[13]Long-run identification schemes go back to *Shapiro and Watson (1988)* and *Blanchard and Quah (1989).*

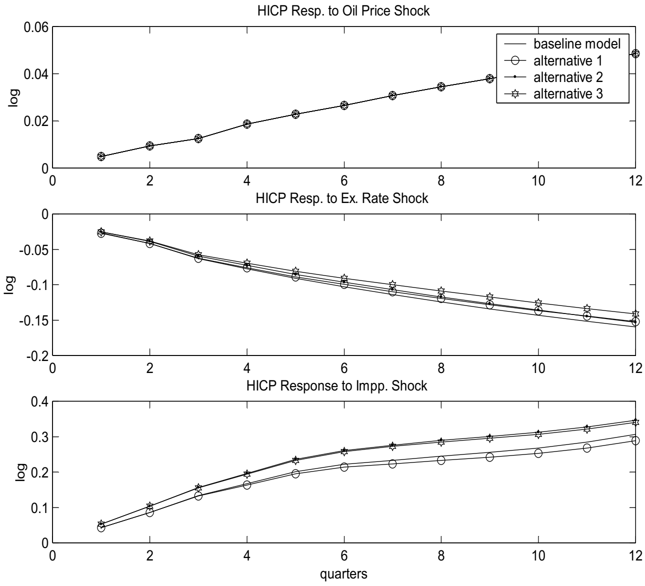

Figure 15: Impulse Responses of the HICP Across Different Orderings

following way: As before, at least $n(n-1)/2 = 21$ economic restrictions are required to uncover the structural shocks. Three of these restrictions are implemented as long-run restrictions. These kind of restrictions are applied to separate demand from supply side shocks. In line with standard macroeconomic models it is assumed that supply side shocks may affect output in the long-run, while the long-run impact of demand side shocks on the level of output is restricted to zero. In our model these long-run output neutrality restrictions are used to discriminate monetary policy, demand and exchange rate shocks, i.e. ϵ_t^i, ϵ_t^y and ϵ_t^e, from the supply side shocks.

Formally, long-run neutrality restrictions are zero restrictions on the matrix $D(1) \equiv \sum_{k=0}^{\infty} D(k)$, that captures the long-run impact of the structural shocks $\epsilon_t = (\epsilon_t^{oil}, \epsilon_t^i, \epsilon_t^y, \epsilon_t^e, \epsilon_t^{impp}, \epsilon_t^{ppi}, \epsilon_t^{hicp})'$ on the level of the endogenous variables. Defining the long-run coefficient matrix of the reduced form model as $C(1) \equiv \sum_{k=0}^{\infty} C(k)$, the long-run neutrality restrictions of monetary policy shocks, demand shocks and exchange rate shocks may be written as in the equations (2) to (4).

$$
\begin{aligned}
D_{32}(1) &= C_{31}(1)S_{12} + C_{32}(1)S_{22} + C_{33}(1)S_{32} + C_{34}(1)S_{42} \\
&\quad + C_{35}(1)S_{52} + C_{36}(1)S_{62} + C_{37}(1)S_{72} = 0 \qquad (2)
\end{aligned}
$$

$$
\begin{aligned}
D_{33}(1) &= C_{31}(1)S_{13} + C_{32}(1)S_{23} + C_{33}(1)S_{33} + C_{34}(1)S_{43} \\
&\quad + C_{35}(1)S_{53} + C_{36}(1)S_{63} + C_{37}(1)S_{73} = 0 \qquad (3)
\end{aligned}
$$

$$
\begin{aligned}
D_{34}(1) &= C_{31}(1)S_{14} + C_{32}(1)S_{24} + C_{33}(1)S_{34} + C_{34}(1)S_{44} \\
&\quad + C_{35}(1)S_{54} + C_{36}(1)S_{64} + C_{37}(1)S_{74} = 0 \qquad (4)
\end{aligned}
$$

The remaining 18 restrictions are imposed as short-run restrictions on the matrix S. Having already separated demand from supply shocks, discrimination between the different demand shocks is achieved through the following zero restrictions. In order to separate demand from exchange rate and monetary policy shocks, we assume that the two latter shocks have no contemporaneous impact on output ("minimum delay restriction"). Considering the lags of the monetary policy transmission on prices, we differentiate further between exchange rate and monetary policy shocks by imposing a further "minimum delay restriction" on the contemporaneous impact of monetary policy on the HICP.[14]

Identification of the supply side shocks is achieved in the following way: Starting with the oil price shocks, in the literature these shocks are usually identified through the assumption that either the contemporaneous effects or the long-run effects of supply and demand shocks on oil prices are zero.[15] We decided in favour of the short-run restrictions as these seem less restrictive for a large economy like the euro area. As regards the other price variables, we impose the restrictions that none of these price shocks contemporaneously affects the exchange rate. In order to distinguish between the price shocks at different price stages we impose the restriction that price shocks at each stage may

[14] As regards price indices that include mortgage interest rates such a restriction obviously would not hold. However, the HICP does not take interest rates into account.

[15] For zero restrictions on the contemporaneous effects of supply and demand shocks on oil prices see, e.g., *Bjornland (1998)* and *Bjornland (2000)*. As regards the long-run restrictions see, e.g., *Bjornland (2001)*, *Landau (2000)* and *Wehinger (2000)*.

contemporaneously affect prices at subsequent stages but not vice versa. As three further restrictions are still open, to better identify import price shocks we further restrict their contemporaneous impact on interest rates to zero. This kind of restriction seems appropriate for a large and relatively closed economy like the euro area.[16] The last two zero restrictions were imposed on the contemporaneous impact of prices on output. More precisely, we decided to restrain the contemporaneous impact of import price and HICP shocks on output to zero. The short-run restrictions on S are summarized in equation (5).

$$\begin{pmatrix} e_t^{oil} \\ e_t^{i} \\ e_t^{y} \\ e_t^{e} \\ e_t^{impp} \\ e_t^{ppi} \\ e_t^{hicp} \end{pmatrix} = \begin{pmatrix} S_{11} & 0 & 0 & 0 & 0 & 0 & 0 \\ S_{21} & S_{22} & S_{23} & S_{24} & 0 & S_{26} & S_{27} \\ S_{31} & 0 & S_{33} & 0 & 0 & S_{36} & 0 \\ S_{41} & S_{42} & S_{43} & S_{44} & 0 & 0 & 0 \\ S_{51} & S_{52} & S_{53} & S_{54} & S_{55} & 0 & 0 \\ S_{61} & S_{62} & S_{63} & S_{64} & S_{65} & S_{66} & 0 \\ S_{71} & 0 & S_{73} & S_{74} & S_{75} & S_{76} & S_{77} \end{pmatrix} \begin{pmatrix} \epsilon_t^{oil} \\ \epsilon_t^{i} \\ \epsilon_t^{y} \\ \epsilon_t^{e} \\ \epsilon_t^{impp} \\ \epsilon_t^{ppi} \\ \epsilon_t^{hicp} \end{pmatrix} \tag{5}$$

The impulse response functions of this model with the corresponding error bands are displayed in the Figures 19 to 21 in the Appendix A. As in the case of the baseline model the impulse responses to oil price shocks were significant over the whole time horizon under consideration. Most of the others were significant over about four quarters. Different from the baseline model, exchange rate and import price shocks did not have a significant impact on the HICP.

Figures 16 to 18 provide a comparison between the impulse response functions derived from the model including short and long run restrictions and those of the baseline model. As can be seen in these Figures, the impulse response functions of the different price indices to an oil price shock are almost identical across the two models. In this case, this results is not by construction, it seems however likely to occur as the estimated oil price shock series of the model including short and long-run restrictions should not have changed much relative to the shock series in the benchmark model. As regards the other shocks larger deviations show up. The most striking difference between the impulse responses of the two models relates to the size of the impact. Comparing the significant

[16] A similar restriction was used by *Peersman and Smets (2001)* for the euro area and by *Eichenbaum and Evans (1995)* as regards the US. They restricted the contemporaneous impact of exchange rate changes on the interest rate to zero.

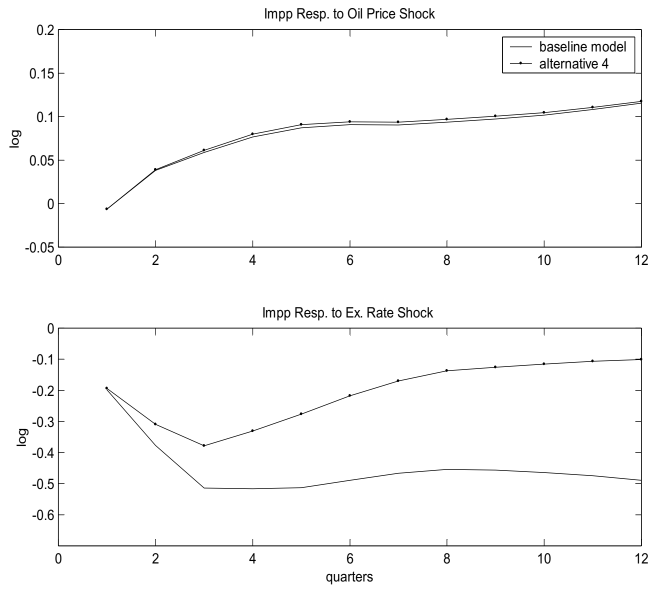

Figure 16: Comparison of Impulse Responses of Non-Oil Import Prices

parts of the impulse responses, the responses of all price indices to exchange rate and non-oil import price shocks are somewhat smaller for the model combining short and long-run restrictions. This is most obvious as regards the insignificant impact of these shocks on the HICP.

6 Conclusions

In this paper we provide empirical evidence on the pass-through of external shocks on inflation in the euro area at different price stages. The analysis is based on a VAR approach including the distribution chain of pricing. In the baseline model identification is achieved through a standard Choleski decomposition. Information on the size and the speed of the pass-through is derived from impulse response functions. According to our results as regards all price indices the pass-through is largest and fastest for import price shocks, followed by exchange rate shocks and oil price shocks. The size and the speed of the pass-through of external shocks decline along the distribution chain of pricing. Our estimates

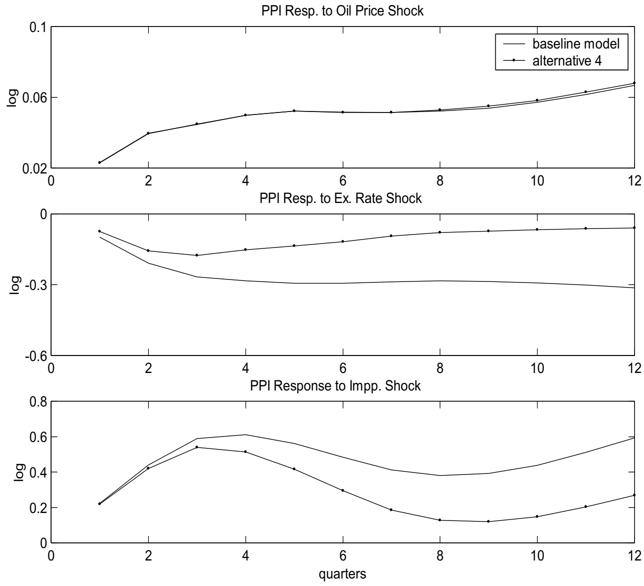

Figure 17: Comparison of Impulse Responses of Producer Prices

on the exchange rate pass-through to import prices seem to be broadly in line with those of *Anderton (2003)*, while those on the exchange rate pass-through to the HICP were twice as large as the findings of *Hüfner and Schröder (2002)*. Variance decompositions indicate that external shocks account for quite large fractions of the variance in all price indices. Historical decompositions for the time period since the start of the EMU show the external shocks seem to have contributed strongly to increase inflation in the euro area since 1999.

The robustness of these results was tested in two ways. First, by estimating the model over the two subsample periods 1971 to 1984 and 1985 to 2002 the robustness of the results over time was analyzed. The size and the speed of the pass-through appeared to be stable over the two subsamples. Variance decompositions over the different periods indicate that the relative importance of external shocks for fluctuations in the different price indices in the euro area seems to have increased over time. Similar observations were reported by *McCarthy (2000)* for a number of industrialized countries. A potential explanation for these developments might be a greater focus of monetary policy on stabilizing the

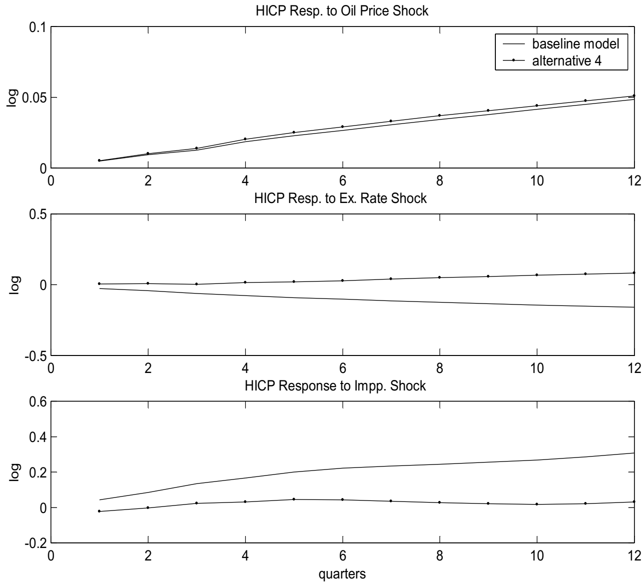

Figure 18: Comparison of Impulse Responses of the HICP

domestic sources of variation in prices in recent years. The estimates as regards the exact contributions of external shocks to inflation in the euro area since 1999 varied substantially across different sample periods. A common result from different sample periods was however that external shocks were strong positive contributors to inflation in the euro area since the start of the EMU. Second, the robustness of the results across different identification schemes was investigated. These results were very robust as regards different plausible orderings in the Choleski decomposition. Almost identical results as regards the responses of the different price indices to oil price shocks, and somewhat smaller effects as regards those to exchange rate and non-oil import price shocks were furthermore derived from a model including short and long-run economic restrictions.

The results presented in this paper for most of the sample period are based on "synthetic" euro area data. Thus, at this point a short final note on the problems associated with the use of these data seems in order. Aside from problems like availability and harmonization of the underlying national data or the possibility of aggregation bias, analysis that apply "synthetic" euro area data are - perhaps even more than other data - susceptible to the Lucas critique, as in the period at hand the "euro area economy" has experienced major changes, crowned with the launch of the EMU. According to this critique such regime shifts may change agents behaviour which in turn may affect the transmission mechanism of shocks. However, to follow *Monticelli and Tristani (1999)* at present no better alternative to applying these data seems at hand. In this line the results derived in this paper provide insights into the pass-through of external shocks on inflation in the euro area, which, interpreted with the necessary caution, could improve the assessment of the monetary policy transmission on prices as well as inflation forecasts in the euro area as regards external impacts.

The analysis conducted in this paper refers to aggregated price indices. In view of the recently observed differences between service price and goods price dynamics in the euro area, an interesting extension to our analysis would be to distinguish further between the pass-through of external shocks on domestic consumer non-tradeables (services) and consumer tradeables (goods). Such a distinction is given a high degree of prominence in the international macroeconomics literature and would also be of great interest to policy makers. We leave this issue for future research.

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A Figures and Tables Appendix

Table 3: Unit Root Tests+

Variable	Notation	ADF Test		PP Test		5 Percent	Decision
		Setup++	Statistic	Setup++	Statistic	Crit. Val.+++	
$log(oil)$	oil	c,t	-2.55	c,t,4	-2.61	-3.44	I(1)
$\triangle log(oil)$	$\triangle oil$	c	-10.37*	c,4	-10.34*	-2.88	
gap_{hp}	gap	1,2	-4.72*	4	-3.75*	-1.94	I(0)
$log(gdp)$	gdp	c,t,1,2	-3.50*	c,t,4	-3.09	-3.44	I(1)
$\triangle log(gdp)$	$\triangle gdp$	c,1	-5.39*	c,4	-8.31*	-2.88	
$log(e)$	e	c,1	-1.78	c,4	-1.67	-2.88	I(1)
$\triangle log(e)$	$\triangle e$		-8.74*	4	-8.76*	-1.94	
$log(impp)$	$impp$	c,t,1	-1.71	c,t,4	-1.42	-3.44	I(1)
$\triangle log(impp)$	$\triangle impp$	c	-3.92*	c,4	-4.56*	-2.88	
$log(ppi)$	ppi	c,t,1,4	-1.15	c,t,4	-1.06	-3.44	I(1)
$\triangle log(ppi)$	$\triangle ppi$	c,1,3	-4.59*	c,4	-3.76*	-2.88	
$log(hicp)$	$hicp$	c,t,1,2,3	-2.05	c,t,4	-0.18	-3.44	I(1)/I(2)
$\triangle log(hicp)$	$\triangle hicp$	c,t,1,3	-2.84	c,t,4	-3.51*	-3.44	
$\triangle^2 log(hicp)$	$\triangle^2 hicp$	c,3	-17.24*	c,4	-16.56*	-2.88	
i	i	c,1	-1.8	c,4	-1.60	-2.88	I(1)
$\triangle(i)$	$\triangle i$		-7.51*	4	-7.52*	-1.94	
$i - \triangle log(hicp) * 4$	r	c,1,3	-2.22	c,4	-2.60**	-2.88	I(0)/I(1)
$\triangle(i - \triangle log(hicp) * 4)$	$\triangle r$	1	-11.23*	4	-17.52*	-1.94	

* indicates significance at the five percent level

** indicates significance at the ten percent level (-2.57)

+ sample period: 1971(3) - 2002(2)

++ c: constant, t: trend, the integers indicate the lags of differenced dependent variables included in the regression (ADF test) and the truncation lag (PP test)

+++ *MacKinnon (1991)* critical values

Table 4: Johansen Cointegration Test[+] for $x_t = (oil_t, i_t, gap_t, e_t, impp_t, ppi_t, hicp_t)$

$H_0 : rank = p$	Trace Statistic	C. Trace Statistic^{++}	5 Percent Critical Values^{+++}
$p = 0$	143.8**	111.30	124.2
$p \leq 1$	106.4**	82.36	94.2
$p \leq 2$	74.5*	57.73	68.5
$p \leq 3$	43.3	33.60	47.2
$p \leq 4$	24.3	18.85	29.7
$p \leq 5$	11.7	9.13	15.4
$p \leq 6$	2.5	1.99	3.8

* indicates significance at the five percent level
** indicates significance at the one percent level
\+ The test was specified with an unrestricted constant, sample period: 1971(3) - 2002(2)
\++ C. Trace Statistic is the trace statistic corrected for small sample, i.e. $T - nm$ instead of T is used, where T is the sample size and n and m are the number of variables and lags in the VAR model.
\+++ *Osterwald-Lenum (1992)* critical values

Table 5: Information Criteria

Lag Order(k)	AIC	SC	HQ
1	-54.13	-53.03*	-53.68*
2	-54.52*	-52.31	-53.62
3	-54.46	-51.13	-53.11
4	-54.30	-49.84	-52.49
5	-53.99	-48.39	-51.72
6	-53.83	-47.07	-51.09

AIC: Akaike Information Criterion
SC: Schwarz Criterion
HQ: Hannan-Quinn Criterion
* indicates the minimum of the column

Table 6: Likelihood Ratio Test (LR)

H_0 vs. H_1	LR-Statistic	Probability
$k = 6$ vs. $k = 5$	54.58	0.27
$k = 5$ vs. $k = 4$	46.09	0.59
$k = 4$ vs. $k = 3$	62.62	0.09
$k = 3$ vs. $k = 2$	77.52*	0.00
$k = 2$ vs. $k = 1$	132.91*	0.00

* indicates significance at the five percent level

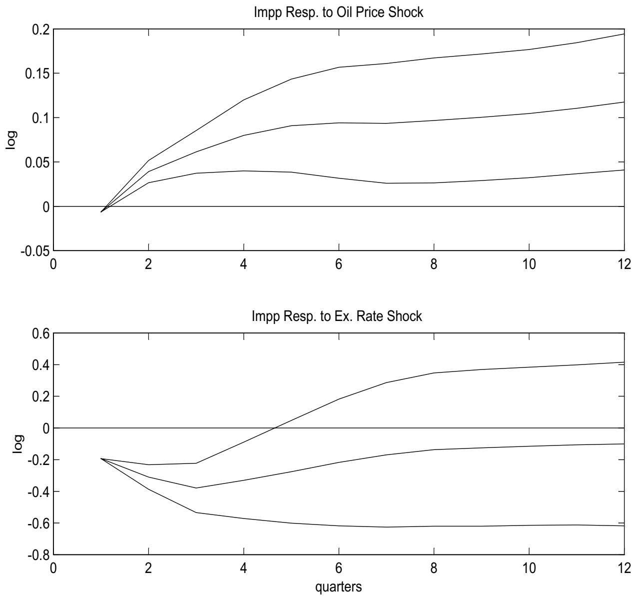

Figure 19: Impulse Responses of Non-Oil Import Prices

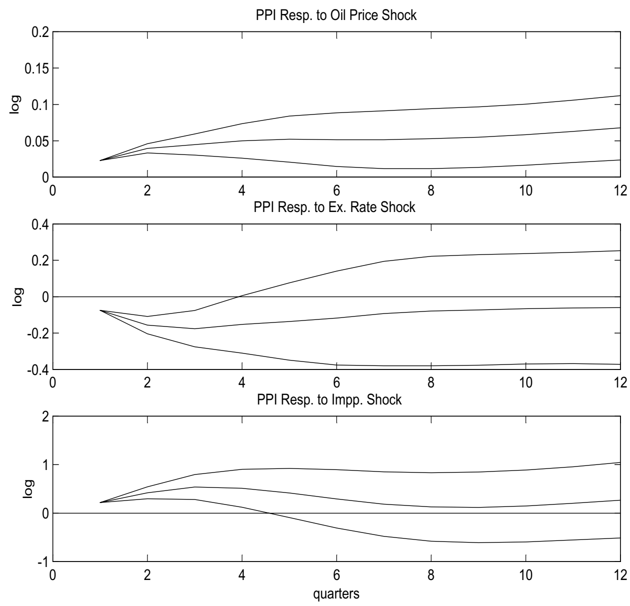

Figure 20: Impulse Responses of Producer Prices

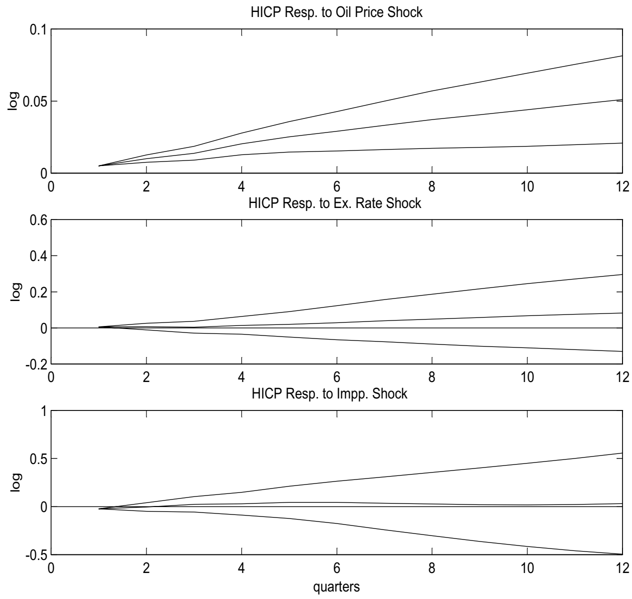

Figure 21: Impulse Responses of the HICP

B Data Appendix

Table 7: Data Sources and Description

Variable	Description	Source
Oil price	US Dollar crude oil price index (1995=100), quarterly average of monthly data.	IMF, IFS
GDP	Real Gross Domestic Product of EMU12[1] valued in billions of Euro, seasonally adjusted	Eurostat, before 1990 ECB calculations
Output gap	Difference between GDP and potential output (derived with the Hodrick-Prescott filter (smoothing parameter 1600))	
Exchange rate	Effective exchange rate of the Euro (1995=100), narrow group of countries, quarterly average of monthly data	ECB calculations
Import prices	Non-oil import deflator (1995=100) of EMU12[1], seasonally adjusted. The import deflator is adjusted for oil price developments by subtraction the oil price index taking into account the oil price weights (volume share) of the import deflator	Eurostat, before 1990 ECB calculations
Producer prices	Producer price index manufacturing (1995=100) of EMU12[1], quarterly average of monthly data, seasonally adjusted (with Census X12)	Eurostat, before 1990 ECB calculations
HICP	Harmonised Index of Consumer Prices (1995=100) of EMU12[1], quarterly average of monthly data, seasonally adjusted (with Census X12)	Eurostat, before 1990 ECB calculations
Interest rate	3-month interest rate of EMU12[1], quarterly average of monthly data, before 1980 data are backdated as weighted averages of the available 3-month interest rates of the EMU countries	ECB calculations, before 1980 OECD, MEI

[1] EMU12: Data refer to the 12 countries participating in the EMU.

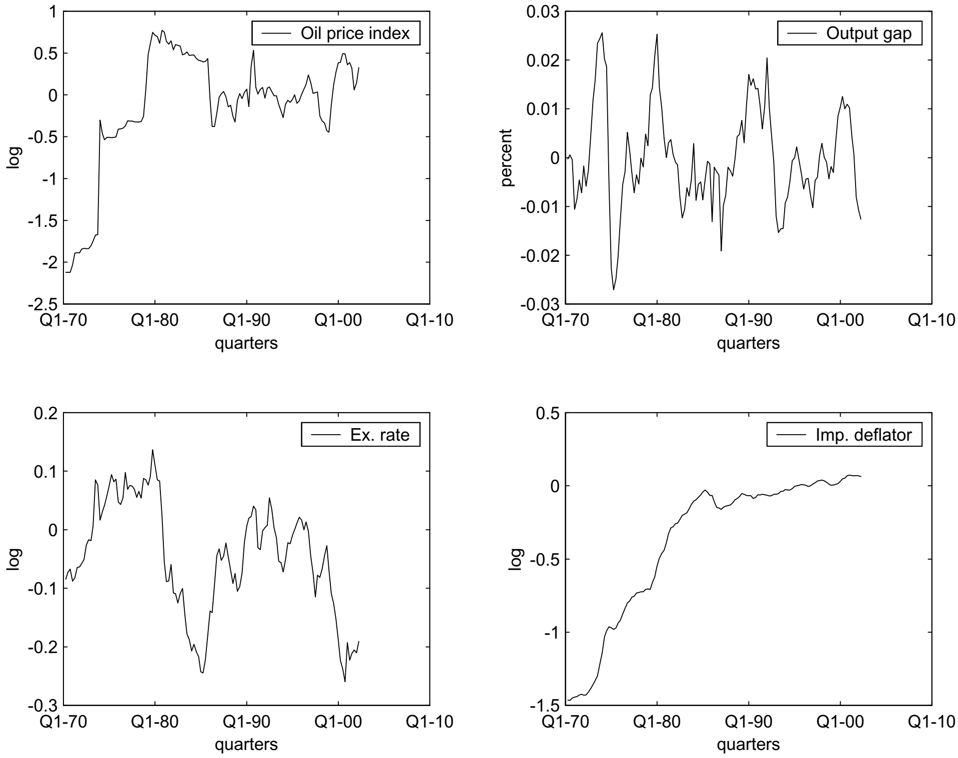

Figure 22: Data Graphics (1)

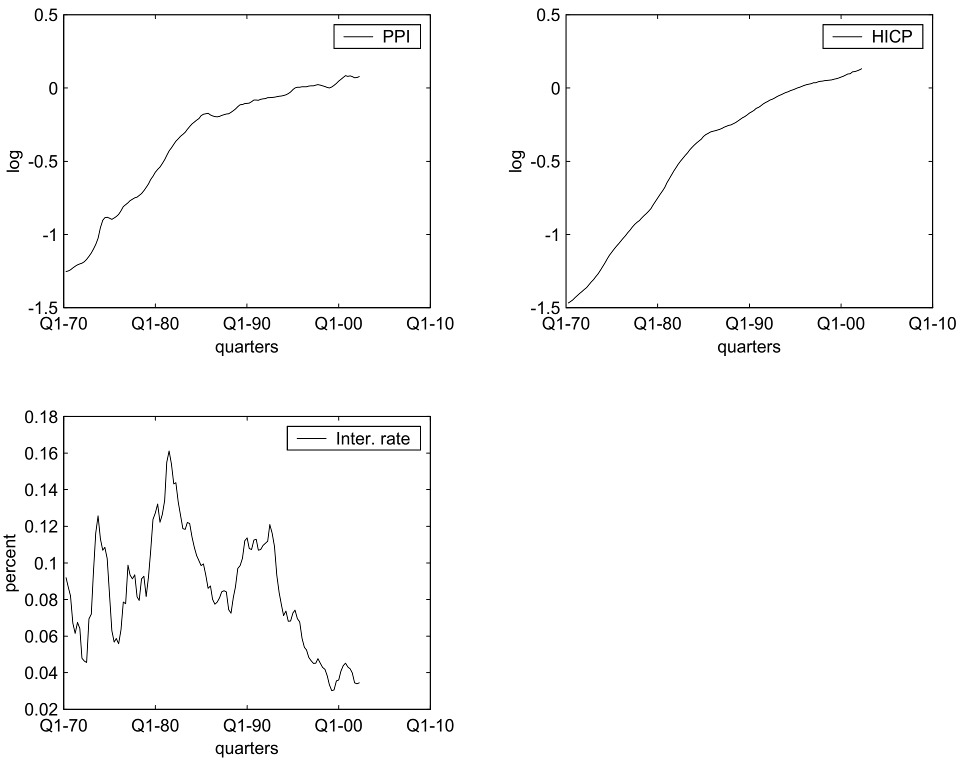

Figure 23: Data Graphics (2)

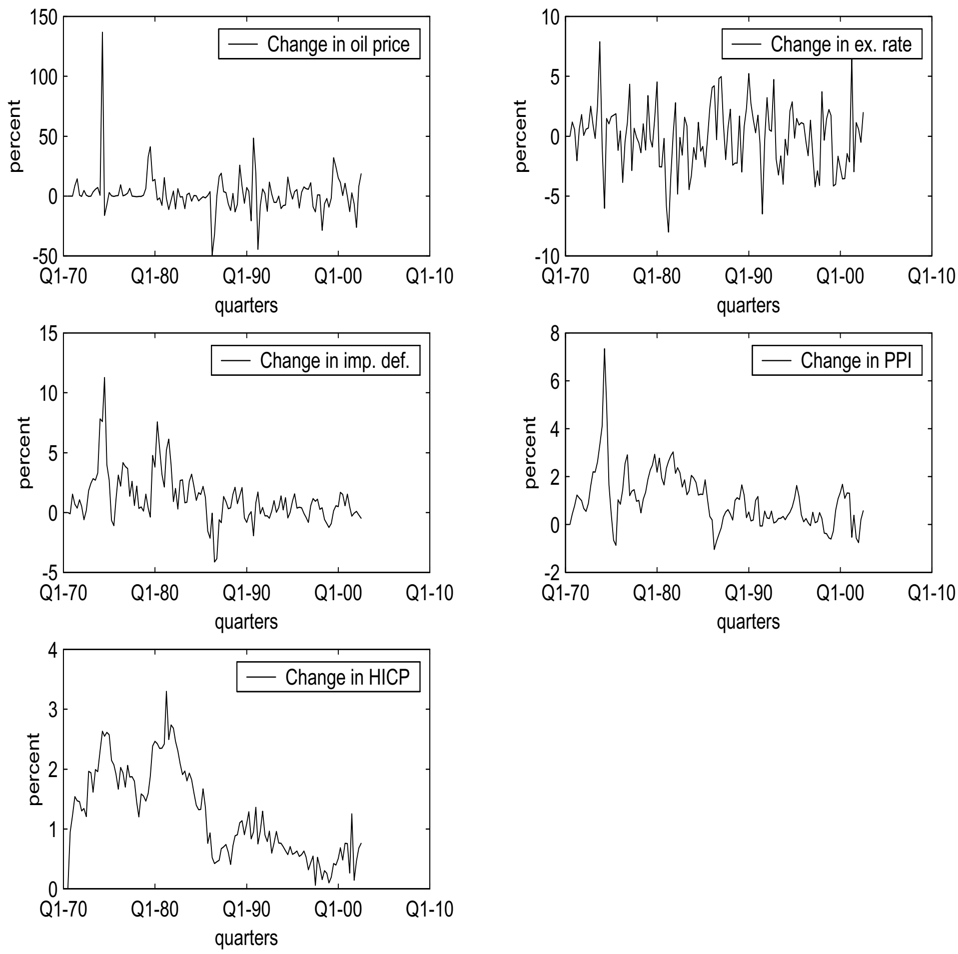

Figure 24: Data Graphics (3)

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