# Oil price pass-through along the price chain in the euro area

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**Abstract**

This paper analyzes how oil price shocks are transmitted downstream to producer and consumer prices in the euro area at the highest disaggregate level. In doing so, we first generate an appropriate database that identifies each industrial production sector with its corresponding price of consumer goods for the euro area. We next estimate a constrained vector autoregressive model. Our findings show a statistically significant increase in producer prices after an oil price shock for branches with high oil consumption, although this statistical pass-through is only partial. However, there is no evidence of a significant oil price pass-through to consumer prices for most branches, which suggests the adaptability of European producers from the most branches to higher oil price pressures without transmitting them to consumers (exceptions: *chemical* and *metal*).

**Keywords:** Oil price, Industrial prices, Consumer prices, Disaggregation
**JEL classification:** E23, E31, Q43

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# 1 Introduction

There is a large body of research on analyzing production reactions to oil price changes (see Lee & Ni (2002), Ramcharran (2002), Fukunaga et al. (2010), among others). The theoretical literature states that crude oil is a basic raw material at many production levels and a rise in its price increases production costs, which give rise to a drop in productivity due to the use of a more costly input. Higher costs seem to be insufficient to explain the observed effects of oil price fluctuations on production (see, e.g., Rotemberg & Woodford (1996), Atkeson & Kehoe (1999)) and the related literature has tried to find complementary explanations. Some of these explanations are based on the gradual decline in the share of oil in total gross value added and consumption (see Blanchard & Galí (2010)),[1] the existence of different manufacturing structures or the rigidities in product and labor markets (see, e.g., Jiménez-Rodríguez (2008), Blanchard & Galí (2010)). Nevertheless, the main effect of an increase in oil price on the industrial production seems to be the fall in domestic demand caused by the cutbacks in consumer expenditures due to lower real and expected incomes. The latter is in line with Davis & Haltiwanger (2001) and Keane & Prasad (1996), who find a fall in wages and employment (at least, in the short run) after an oil price shock. The fall in wages and employment exacerbates the fall in consumer income and thus generates additional reductions in domestic demand. Therefore, the main concern for producers would come from the uncertainty about the depth and duration of an oil price shock and its impact on the future consumer demand, as well as the subsequent reaction of monetary policy. The reactions of consumers and monetary policy are precisely those that most affect the producers and those on which the empirical literature has put more emphasis (see, e.g., Lee & Ni (2002), Kilian (2008), Hamilton (2009), Blanchard & Galí (2010)).

The literature has also analyzed the main mechanisms through which producers make adjustments to deal with an increase in oil prices: (i) producers may transfer higher costs to consumers, which causes an increase in non-energy inflation and a subsequent fall in the demand;[2] (ii) producers may reduce production[3] since they expect that consumers decrease demand for their products

[1]For example, Álvarez et al. (2011) show that the share of oil and fuels costs in total economy is only 3.4% in Spain and 2.9% in the euro area. Edelstein & Kilian (2007) indicate that energy share in value added (the sum of nominal value added in oil and gas extraction and imports of petroleum and petroleum products divided by nominal GDP) is 3.3% for the U.S. in 2005.

[2]Lescaroux & Mignon (2008) highlight that such a producers' reaction clearly explains the effects of oil price shocks in the early 1970s, but it is not considered relevant in the shocks of the 2000s for three reasons: the increased credibility of monetary policy, lower indexation wages and higher international competition between companies.

[3]Rotemberg & Woodford (1996) estimate that the reduction in production originated by higher costs is small and can be amplified if companies cannot offset higher production costs by reducing wages. In this line, Keane & Prasad (1996) find that real wages (and employment at the short run) are reduced as a result of an oil price shock. Lee & Ni (2002) suggest that an oil price shock reduces production, planned investment or employment only in oil intensive sectors like oil refining and the chemical industry. Davis & Haltiwanger (2001) also study the effects of oil price shocks on the U.S. industries, especially during the shock of 1973 and the fall

and thus the lower production level would prevent the fall in prices; (iii) producers may reduce investment, although the degree of adjustment will depend on the intensity of use of energy in production and the elasticity of substitution by other less energy intensive technologies (see Lee & Ni (2002), ECB (2010));[4] (iv) producer may support technological upgrading to maintain the production level, treating thus an energy shock as a productivity shock;[5] (v) producers may reallocate resources given that changes in consumption patterns induced by an oil price shock can give rise to a sectoral reallocation;[6] and (vi) producers may increase inventories in order to reduce temporarily the supply, assuming that the oil price shock will not be long lasting (see Herrera (2006)).

Despite the fact the large literature on production reactions and producers' adjustments after an oil price shock, there is no study that analyzes the patterns of oil pass-through along the price chain at a disaggregate level. However, this analysis is crucial to forecast consumer prices and so to determine the appropriate monetary policy.

This paper extends the empirical work on oil price impacts by analyzing the oil pass-through along the price chain in the euro area (EA) by using disaggregate data at the industry level.[7] To do so, we have first to generate an appropriate database due to there is no available database that identify industrial production sectors with their corresponding consumer goods at a disaggregate price level. Once we match the industrial production sectors with their corresponding consumer goods at the highest level of disaggregation, we investigate the oil price pass-through in the euro area by considering a pricing chain approach and by analyzing how shocks in oil prices are transmitted downstream to producer and consumer prices.[8]

Our main findings may be summarized as follows. We find evidence of

in employment on the U.S. automotive sector. In the European countries, Jiménez-Rodríguez (2008) finds that oil price increases have a negative impact on industrial production at the sectoral level.

[4]Bernanke (1983) shows that companies reduce their irreversible investment in durable goods until they are sure of the duration and intensity of the oil price change. More recently, some authors do not find arguments to support the reduction in investment as a result of an oil price shock (see Edelstein & Kilian (2007)).

[5]Atkeson & Kehoe (1999) argue that the product falls in the long term even when the producers adopt less intensive capital and energy technologies. Hamilton (1988) marks, from a flexible pricing model, the appearance of frictional unemployment as workers seek to work in other sectors. The adoption of energy-saving technologies in production is also one of the reasons why Blanchard & Galí (2010) and Bachmeier & Cha (2011) explain the progressive reduction of the effects of the oil price shocks on the non-energy inflation.

[6]Davis & Haltiwanger (2001) argue that technological rigidities or markets do not allow rapid conversion of production and may lead to reduction of an entire industrial sector. This was the case of the automobile industry in the U.S. during the shocks of the 1970s (see Lee & Ni (2002), Edelstein & Kilian (2009)). Davis & Haltiwanger (2001) study the effects on sectoral employment and show that an oil price shock increases job losses and reduces its creation after four months of the shock, with a negligible effect after 2 years, but with the reallocation of employment.

[7]Authors such as Jiménez-Rodríguez (2008) and Herrera et al. (2011) have highlighted the relevance of a disaggregated analysis of the industrial production.

[8]The pricing chain approach has been previously used by authors such as Ferrucci et al. (2012).

a partial oil price pass-through to producer prices for branches with high oil consumption and a negligible pass-through for the other branches. Moreover, oil price pass-through to consumer prices is very low in general and is only relevant for two branches (*chemical* and *metal*), which suggests the adaptability of European producers from the most branches to higher oil price pressures without transmitting them to consumers (exceptions: *chemical* and *metal*). Therefore, we show that the industrial production fall may be explained by the increase in producer prices (mainly for branches with higher oil consumption) after the oil shock and also by the adjustment in the production level for avoiding the transmission of higher costs to consumer prices. As a consequence, the design of the monetary policy reaction in the euro area should consider the fact that inflation risks do not seem to arise from supply shocks, but from the demand shocks.

The paper is organized as follows. Section 2 discusses the data. Section 3 describes the model. Section 4 shows the results.

## 2 Data

We use monthly disaggregate EA[9] data at the industry level on producer price index ($ppi_t$)[10] and the Harmonised index of consumer price ($hicp_t$), as well as the nominal Brent price in € ($poil_t$). The longest available sample period for disaggregate data runs from January 2000 to November 2015. The producer and consumer price data are downloaded from the Eurostat database (http://ec.europa.eu/eurostat). The nominal oil price data in US dollars and the US dollar to euro exchange rate data come from US Energy Information Administration (http://www.eia.gov) and European Central Bank (http://www.ecb.europa.eu), respectively.

As pointed out previously, there is no available database that identify industrial production sectors with their corresponding consumer goods at a disaggregate price level. Thus, we make a correspondence between the industrial production sectors and consumer prices. We first identify 31 industrial branches (from the NACE, Revision 2 classification)[11] that use oil in support of its primary activities according to the international methodology for oil statistics.[12]

[9]Euro area refers to EA-18, which consists of Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Greece, Slovenia, Cyprus, Malta, Slovakia, Estonia and Latvia.

[10]Eurostat indicates that "producer price index shows the development of transaction prices for the monthly industrial output of economic activities. Overall, it measures the average price development of all goods and related services on both the domestic and the non-domestic markets, at all processing stages".

[11]The statistical classification of economic activities in the European Community, abbreviated as NACE, is the classification of economic activities in the European Union.

[12]In oil statistics, oil is used in transformation sector (quantities of oil transformed into another energy form, i.e. generation of electricity and heat), energy sector (oil consumed by the energy sector to support the extraction or plant operation of transformation activities) and total final consumption (transport, industry and other sectors). Consequently, we use total final consumption in industry, excluding the use of oil in other sectors, and therefore

Among these industrial branches, there are only nineteen related to the supplies or direct production of 49 consumer goods which are identified according to COICOP/HICP classification.[13] Thus, we obtain for each producer price index an equivalent group of Harmonised index of consumer price by aggregating all the related consumer price indices with their corresponding weights (see Appendix).[14] For clarification purposes, we next show how we have made the match between the industrial production sectors and consumer prices for one particular industrial branch. The industrial branch named *Manufacture of wearing apparel* (NACE rev. 2 code 14) is dedicated to the production of two consumer goods: *Garments* and *Other articles of clothing and clothing accessories* (COICOP/HICP codes 03.1.2 and 03.1.3, respectively). Therefore, the producer price index for *Manufacture of wearing apparel* is matching with the consumer price index obtained from the weighted aggregation of the corresponding two consumer price indices (*Garments* and *Other articles of clothing and clothing accessories*).[15]

Once we match the industrial production sectors with their corresponding consumer goods, we analyze the seasonal and non-stationary behavior of the log transformed indices. Table 1 shows the main results for producer and consumer prices. We observe that most of the producer and consumer price indices display seasonality and, consequently, we have performed a seasonal adjustment procedure using the TRAMO-SEATS.[16] On the contrary, $poil_t$ does not show seasonal fluctuations.

Once the producer and consumer price indices have been seasonally adjusted, we investigate the stationarity of the log levels by using the augmented Dickey-Fuller (ADF) test, whose the null hypothesis is the existence of a unit root. We cannot reject the null hypothesis for oil prices (not shown in the table),[17] eighteen producer price indices and seventeen consumer price indices (see Table 1). Despite the fact there is one producer price and two consumer prices in which stationary in the log-levels is found, we have decided to do the first log-differences for all indices for interpretation purposes.

We now investigate whether the past values of oil price changes ($\Delta poil_t$) help predict the value of the changes in the producer price index of branch $b$

we do not take into account costs generated for providing consumer goods and services, as transport. See, for example, the methodology in http://www.iea.org.

[13]The COICOP/HICP is the United Nations Classification of individual consumption by purpose (COICOP), which was adapted to the compilation of the Harmonised index of consumer prices (HICP) of the European Union and the euro area.

[14]We use the annual weights for each COICOP/HICP item from 2000 to 2014 published by Eurostat. The information used by Eurostat to calculate the weight of each product group is collected mainly by means of household budget surveys and therefore is representative for the average household consumption expenditure. See methodology in https://www.ecb.europa.eu.

[15]See details in the Appendix.

[16]We implement the multi processing seasonal adjustment with JDemetra+, available at European Statistical System (http://ec.europa.eu/eurostat/).

[17]The $p$-values of ADF test for oil prices are 0.59 and 0.01 for the log-levels and the first log-differences of oil prices, respectively.

Table 1: Seasonal adjustment and unit root test.

| | | Producer price index, $ppi_t^b$ | | | | | Consumer price index, $hicp_t^b$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $b$ | branch | | log-level | | $\Delta$ | | | log-level | | $\Delta$ | |
| 1 | mining | SA | 0.30 | | -7.41 | *** | SA | 1.06 | | -7.38 | *** |
| 2 | food | | -2.45 | | -4.11 | *** | SA | -1.95 | | -6.86 | *** |
| 3 | beverages | SA | -1.51 | | -7.47 | *** | SA | -1.25 | | -4.90 | *** |
| 4 | tobacco | SA | -1.64 | | -10.67 | *** | | -0.71 | | -9.31 | *** |
| 5 | textile | SA | -1.03 | | -5.07 | *** | SA | -1.64 | | -12.04 | *** |
| 6 | apparel | SA | -1.76 | | -8.01 | *** | SA | -5.13 | *** | -13.56 | *** |
| 7 | leather | SA | -0.68 | | -7.95 | *** | SA | 0.05 | | -8.26 | *** |
| 8 | wood | | -1.79 | | -4.80 | *** | SA | 1.36 | | -6.18 | *** |
| 9 | paper | | -2.74 | | -4.53 | *** | SA | -0.52 | | -5.78 | *** |
| 10 | recorded | | -4.20 | *** | -8.66 | *** | SA | -1.66 | | -5.43 | *** |
| 11 | chemical | SA | -2.36 | | -6.54 | *** | SA | -2.04 | | -8.84 | *** |
| 12 | non-metallic | SA | 0.16 | | -4.49 | *** | SA | 1.08 | | -3.36 | *** |
| 13 | basic metals | | -1.50 | | -4.67 | *** | | -0.86 | | -4.71 | *** |
| 14 | metal | SA | -0.06 | | -4.84 | *** | SA | -0.36 | | -5.02 | *** |
| 15 | electronic | | 1.43 | | -8.10 | *** | SA | -1.17 | | -6.08 | *** |
| 16 | electrical | SA | -1.09 | | -4.79 | *** | SA | -0.77 | | -5.90 | *** |
| 17 | machinery | SA | -0.88 | | -7.49 | *** | SA | -3.64 | ** | -6.24 | *** |
| 18 | motor | | -3.09 | | -9.62 | *** | SA | -1.28 | | -7.70 | *** |
| 19 | transport | | -2.75 | | -13.64 | *** | SA | 0.41 | | -5.77 | *** |

**Note:** Seasonal adjustment (SA) series and ADF test statistics for log-levels and 1st log-differences ($\Delta$) of each branch $b$. The null hypothesis is that a unit root exists. One/two/three asterisks denote significance at the 10%, 5% and 1% levels, respectively.

($\Delta ppi_t^b$):

$$\Delta ppi_t^b = c^{b,1} + \sum_{j=1}^{p} \alpha_j^1 \Delta ppi_{t-j}^b + \sum_{j=1}^{p} \beta_j^1 \Delta poil_{t-j} + \mu_t^{b,1} \tag{1}$$

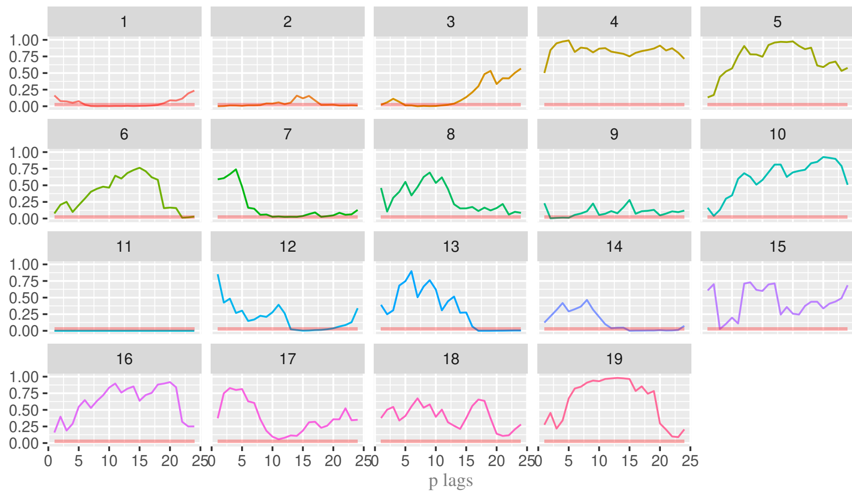
We also test whether changes in the producer price index of branch $b$ directly induced by changes in oil prices ($\Delta ppi\_oil_t^b$)[18] help predict changes in the consumer price index of branch $b$ ($\Delta hicp_t^b$) :

$$\Delta hicp_t^b = c^{b,2} + \sum_{j=1}^{p} \alpha_j^2 \Delta hicp_{t-j}^b + \sum_{j=1}^{p} \beta_j^2 \Delta ppi\_oil_{t-j}^b + \mu_t^{b,2} \tag{2}$$

where $p = 1, 2, \ldots 24$ and $b = 1, 2, \ldots 19$ branches. We use an $\chi^2$-statistics to test for the null hypothesis that $\beta_1^k = \beta_2^k = \cdots \beta_p^k = 0$ with $k = 1, 2$.

Instead of evaluating the Granger-causality (G-causality) test for a convenient $p$ lag, we take into account the Hamilton & Herrera (2004)'s warning about the convenience of including a rich lag structure in studying the effects of oil prices on macroeconomic variables. Then, we investigate the sensitivity of the G-causality test to the choice of lag length $p = 1, 2, \ldots 24$, obtaining their corresponding $p-$values.

[18]Following a referee's suggestion, we have first tested for the Granger-causality from changes in oil prices to changes in the producer price index of branch $b$ and then the Granger-causality from the component of producer price changes of branch $b$ directly explained by oil prices to changes in the consumer price index of branch $b$. In doing so, we have calculated the component of producer price changes of branch $b$ directly explained by oil prices assuming, for sake of simplicity, 24 lags. We are indebted to an anonymous referee for this point.




Note: This Figure presents the p−values for G−causality test for b=1,2,...,19 branches and p=1,2,..,24 lags.
p−values < 0.05 (bottom shaded area in red) rejects the null hypothesis.

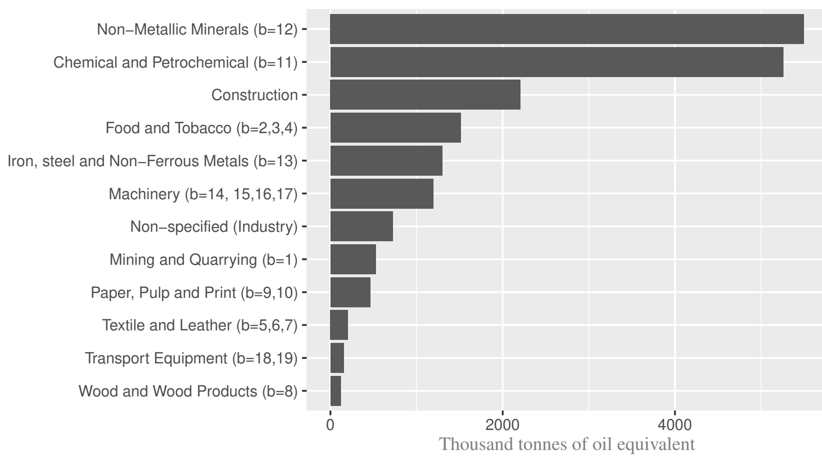
Figure 1: G-causality test (Ho: $\Delta poil_t$ does not G-cause $\Delta ppi_t^b$)

Figure 1 indicates that oil price changes G-cause industrial price changes (at least, for some lag) in twelve out of nineteen branches. As expected, G-causality is found for the industrial sectors with the highest oil consumption (see Figure 2).[19] We find that evidence of G-causality when more than 12 lags are included for the branch 12, the *non-metallic* branch (the branch with the highest relative consumption of oil). We also obtain that oil price changes help predict the branch 11 (the *chemical* branch) for any lag. In contrast, we do not find G-causality at any lag for branches with the lowest consumption of oil (*wood* branch, $b$=8).

Figure 3 shows that industrial price changes directly induced by changes in oil prices G-cause consumer price changes in several branches (7 out of 19) for, at least, some lag.

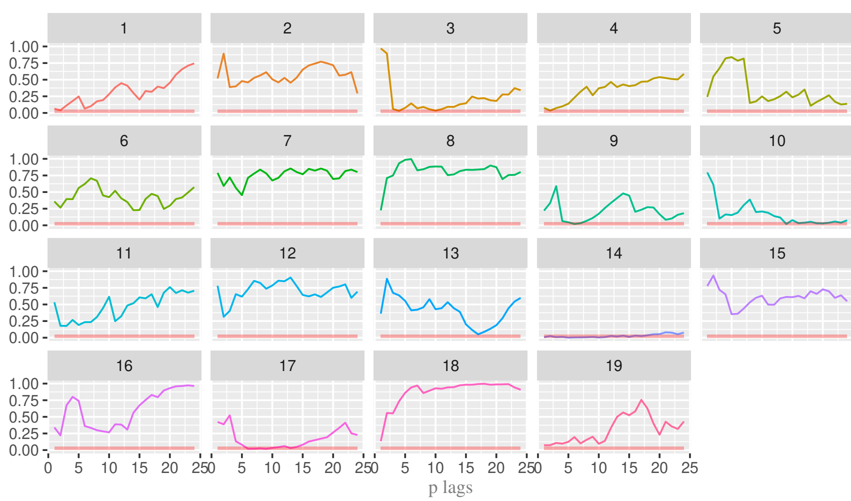
Therefore, the pricing chain approach adopted in this paper finds some support in the results of the G-causality test.

[19]There are no data of final consumption in total petroleum products that perfectly coincide with the branches used in this paper. Thus, we have done a correspondence between the branches of this paper and the industrial sectors for which there are data of final consumption in total petroleum products. Specifically, we have used the following identification: *Non-Metallic Minerals*=branch 12; *Chemical and Petrochemical Products*=branch 11; *Food and Tobacco*=branches 2, 3, 4; *Iron, Steel* and *Non-Ferrous Metals*=branch 13; *Machinery*=branches 14, 15, 16, 17; *Mining and Quarrying*=branch 1; *Paper, Pulp and Print*=branches 9, 10; *Textile and Leather*=branches 5, 6, 7; *Transport Equipment*=branches 18, 19; and *Wood and Wood Products*=branch 8.




Note: This Figure shows the final consumption in total petroleum products by industrial sectors in the Euro area (19 countries) in 2013. b represents the approximation with the branches defined in the Appendix. Data source: Eurostat.

Figure 2: Final consumption in total petroleum products by industrial sectors.




Note: This Figure presents the p−values for G−causality test for b=1,2,...,19 branches and p=1,2,..,24 lags. p−values < 0.05 (bottom shaded area in red) rejects the null hypothesis.

Figure 3: G-causality test (Ho: $\Delta ppi\_\text{oil}_t^b$ does not G-cause $\Delta hicp_t^b$).

# 3 The Model

It is our aim to analyze the oil pass-through along the price chain in the EA at disaggregate level. To do so, we consider a $p$th-order VAR for each branch $b$ with oil price changes ($\Delta poil_t$), changes in the producer price index ($\Delta ppi_t^b$) and changes in the consumer price index ($\Delta hicp_t^b$) as variables. Thus, the reduced form of VAR(p) is written as

$$Y_t = a + \sum_{j=1}^{p} \Phi(p) Y_{t-1} + \varepsilon_t \tag{3}$$

for each branch, with $Y_t = (\Delta poil_t, \Delta ppi_t^b, \Delta hicp_t^b)$ and with $\varepsilon_t$ being a generalization of a white noise process with variance-covariance matrix $\Omega$.

Although it is common in the literature on the effects of oil prices to consider oil prices as endogenous variable (see, e.g., Kilian (2008)), the use of disaggregated data in a region like the euro area previously required test for whether domestic disaggregated prices cause oil prices. Thus, we apply a block-exogeneity test with the null hypothesis that oil price changes are not Granger-caused by changes in the producer price index and the Harmonized index of consumer price of the branch $b$. Table 2[20] shows that the null hypothesis cannot be rejected for all branches except for *food* ($b = 2$), *chemical* ($b = 11$), *basic metals* ($b = 13$) and *metal* ($b = 14$). Consequently, we consider a VAR(p) in which we do not allow that domestic price variables affect oil price changes for all branches but the exception previously mentioned (given the results of the block-exogeneity test), but we allow the latter variable affects the former variables.

Thus, we estimate the following VAR(p) model:

$$\begin{pmatrix} \Delta poil_t \\ \Delta ppi_t^b \\ \Delta hicp_t^b \end{pmatrix} = \begin{pmatrix} a_1 \\ a_2 \\ a_3 \end{pmatrix} + \sum_{j=1}^{p} \begin{pmatrix} \phi_{11}^{(j)} & \phi_{12}^{(j)} & \phi_{13}^{(j)} \\ \phi_{21}^{(j)} & \phi_{22}^{(j)} & \phi_{23}^{(j)} \\ \phi_{31}^{(j)} & \phi_{32}^{(j)} & \phi_{33}^{(j)} \end{pmatrix} \begin{pmatrix} \Delta poil_{t-j} \\ \Delta ppi_{t-j}^b \\ \Delta hicp_{t-j}^b \end{pmatrix} + \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \end{pmatrix} \tag{4}$$

with $\phi_{12}^{(j)}$ and $\phi_{13}^{(j)}$ being zero for all $j$ and for all branches but *food*, *chemical*, *basic metals* and *metal*.

[20]The VAR(p) can be written as follows:

$$\Delta poil_t = a_1 + B_1' x_{1t} + B_2' x_{2t}^{(b)} + \varepsilon_{1t}$$

$$x_{2t}^{(b)} = a_2 + D_1' x_{1t} + D_2' x_{2t}^{(b)} + \varepsilon_{2t}$$

where $x_{1t}$ contains lags of $\Delta poil_t$ and $x_{2t}^{(b)}$ is a vector $(2{\cdot}p \times 1)$ vector containing lags of changes in the producer price index ($\Delta ppi_t^b$) and the harmonized index of consumer price of branch $b$ ($\Delta hicp_t^b$). We use the following test statistic to test for whether $\Delta ppi_t^b$ and $\Delta hicp_t^b$ Granger-cause $\Delta poil_t$ (i.e., $B_2 = 0$):

$$T \times \{\log|\sigma^2(0)| - \log|\sigma^2|\} \overset{a}{\sim} \chi^2(2p)$$

where $\sigma^2$ is the variance of the residuals from OLS estimation of (3) and $\sigma^2(0)$ that of the residuals from OLS estimation of model (3) when $B_2 = 0$.

Table 2: Block exogeneity test.

| | branch | lags | statistic | | p-value |
|---|---|---|---|---|---|
| 1 | mining | 3 | 1.1917 | | 0.3091 |
| 2 | food | 2 | 2.7595 | ** | 0.0272 |
| 3 | beverages | 7 | 0.8739 | | 0.5877 |
| 4 | tobacco | 9 | 1.1858 | | 0.2683 |
| 5 | textile | 8 | 1.1145 | | 0.3380 |
| 6 | apparel | 4 | 0.4044 | | 0.9181 |
| 7 | leather | 6 | 0.8512 | | 0.5974 |
| 8 | wood | 12 | 0.3682 | | 0.9977 |
| 9 | paper | 10 | 0.8245 | | 0.6841 |
| 10 | recorded | 6 | 0.5666 | | 0.8692 |
| 11 | chemical | 10 | 1.7228 | ** | 0.0271 |
| 12 | non-metallic | 12 | 0.4536 | | 0.9888 |
| 13 | basic metals | 11 | 1.6495 | ** | 0.0331 |
| 14 | metal | 12 | 1.8741 | *** | 0.0080 |
| 15 | electronic | 6 | 1.5454 | | 0.1044 |
| 16 | electrical | 5 | 0.9199 | | 0.5144 |
| 17 | machinery | 6 | 0.77 | | 0.6817 |
| 18 | motor | 12 | 1.0633 | | 0.3833 |
| 19 | transport | 7 | 1.1817 | | 0.2857 |

**Note:** One/two/three asterisks mean a $p$-value less than 10%, 5% and 1%, respectively.

We estimate by maximum likelihood, with the optimal lag length chosen on the basis of the sequential modified likelihood ratio (LR) test with an upper bound of 12 lags and a lower bound of 1 lag.[21] Moreover, shocks are identified by means of a standard Cholesky decomposition with the variables ordered as follows: $\Delta poil_t$, $\Delta ppi_t^b$ and $\Delta hicp_t^b$. We obtain the impulse responses to an oil price shock and their corresponding 90%, 95% and 99% confidence bands calculate by means of a bootstrapping procedure.[22]

# 4 Results

This section presents the accumulated impulse responses to a 1% oil price shock, which come from a constrained VAR(p) for all branches except *food, chemical, basic metals* and *metal*, in which an unrestricted VAR(p) model is used. Table 3 shows the accumulated responses of producer price index of branch $b$ (in percentages) to a 1% oil price shock. For the sake of conciseness, we show the accumulated responses in quarters rather than months. Moreover, we follow the more conservative approach and we refer to significant response whenever the response is statistically significant, at least, at the 5% critical level.

[21] As a robustness check (available upon request), we also estimate the model considering 12 lags. The main conclusions of the paper are valid with the use of 12 lags for all branches. We thank a referee for this suggestion.

[22] We apply the Efron bootstrap percentile confidence interval with 2500 draws.

We observe that an increase in oil prices leads to higher industrial production prices for most of branch, which is consistent with a natural subsequent increase in industrial costs given that crude oil has been a basic input to production, and that oil price pass-through to producer prices is not complete. However, the patterns of pass-through from oil prices to producer prices differ across branches. The branches with higher oil consumption (see Figure 2) are those in which the impact of an oil shock are statistically significant (*non-metallic, chemical, food, beverages, basic metals, metal, electrical, mining* and *paper*). In particular, the *basic metals* and *chemical* branches (which show very high oil consumption) have the largest significant accumulated effects, with an impact of 0.215% and 0.180% after one year, respectively. Therefore, it seems that there is a link between oil consumption and accumulated responses shown in Table 3.[23] The branches with the highest oil consumption (*non-metallic, chemical, food, beverages* and *basic metals*) show statistically significant responses to oil price shocks and those with the lowest oil consumption (*wood, motor* and *transport*) do not response significantly to oil shocks. Therefore, an oil price shock seems to increase industrial costs according to the intensity of final consumption of oil.

We are also interested to assess the transmission of higher oil prices to consumer prices. Table 4 shows the accumulated responses of consumer prices of branch $b$ to a 1% increase in oil prices. We observe that an unanticipated oil price increase leads to a statistically significant increase in consumer prices for only two branches (*chemical* and *metal*). These branches also have significant responses of producer prices to an oil price shock, but there are seven branches with a significant impact of oil prices on producer prices (*non-metallic, food, beverages, basic metals, electrical, mining* and *paper*) that do not show a significant response of consumer prices to an oil shock. The impact of an oil price shock on producer prices is relatively similar to the one on consumer prices for *chemical* and *metal*, which seems to indicate that the pass-through from producer prices to consumer prices is almost complete. Therefore, it seems that most of the increase in the production costs driven by an oil price shock does not transfer into inflation (with the exceptions previously highlighted).

In short, we have found evidence that an increase in oil prices leads to higher producer prices for branches with high levels of oil consumption, in line with other studies (see e.g., Lee & Ni (2002), Fukunaga et al. (2010)).[24] Nevertheless, even in one of the highest oil-intensive branch (*basic metals*), industrial prices

[23] It is worth noting that the effect of a 1% increase in oil price on the most oil-intensive branch (*non-metallic* minerals) is 0.0256% after one year, which is lower than other less oil-intensive branches (*chemical* or *basic metals*). This result may be partially explained by the fact that there are other factors such as the weights and costs of other inputs that may have an influence in the reaction of producer prices to oil price shocks. Also, the reduction in the consumption of petroleum products observed in all industrial branches (but *chemical*) in the last fifteen years may have an influence in the producer price responses to oil price shocks.

[24] Lee & Ni (2002) show in a VAR model that oil price shocks reduce the supply of oil-intensive industries in the US (*petroleum refinery* and *industrial chemical*). Fukunaga et al. (2010) suggest shifts in the oil price driven by either of the two oil demand shocks (global or oil-specific demand) cause an increase in most industrial prices in the US and Japan.

Table 3: Accumulated impulse responses of producer price index (in percentages) attributed to a 1% oil price shock.

| | branch | lags | quarter 1 | | quarter 2 | | quarter 3 | | quarter 4 | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | mining | 3 | 0.0051 | | 0.0107 | * | 0.0143 | ** | 0.0162 | ** |
| 2 | food | 2 | 0.0179 | ** | 0.0289 | ** | 0.0348 | ** | 0.0381 | * |
| 3 | beverages | 7 | 0.0056 | ** | 0.0072 | | 0.0125 | ** | 0.0154 | ** |
| 4 | tobacco | 9 | 0.0017 | | 0.0095 | | 0.0018 | | 0.0115 | |
| 5 | textile | 8 | 0.0043 | | 0.0084 | | 0.0115 | | 0.014 | |
| 6 | apparel | 4 | 0.0022 | | -0.0009 | | -0.0022 | | -0.0026 | |
| 7 | leather | 6 | 0.0037 | | 0.0049 | | 0.0134 | | 0.0148 | |
| 8 | wood | 12 | 0.0052 | | 0.0148 | | 0.0242 | | 0.034 | * |
| 9 | paper | 10 | 0.0129 | * | 0.0309 | ** | 0.0413 | ** | 0.0335 | |
| 10 | recorded | 6 | 0.0005 | | 0.0021 | | 0.0008 | | 0.0012 | |
| 11 | chemical | 10 | 0.1127 | *** | 0.1669 | *** | 0.1671 | *** | 0.18 | *** |
| 12 | non-metallic | 12 | 0.0066 | *** | 0.0122 | *** | 0.0182 | *** | 0.0256 | *** |
| 13 | basic metals | 11 | 0.09 | *** | 0.139 | *** | 0.1814 | ** | 0.2152 | ** |
| 14 | metal | 12 | 0.0079 | | 0.018 | * | 0.0297 | ** | 0.0394 | ** |
| 15 | electronic | 6 | -0.0078 | | -0.017 | | -0.0316 | | -0.0328 | |
| 16 | electrical | 5 | 0.003 | ** | 0.0048 | * | 0.0065 | * | 0.0079 | * |
| 17 | machinery | 6 | 0.0017 | | 0.0043 | | 0.0069 | * | 0.0084 | * |
| 18 | motor | 12 | 0.0012 | | -0.0014 | | 0.0007 | | 0.0065 | |
| 19 | transport | 7 | 0.0023 | | 0.0009 | | -0.0014 | | -0.0035 | |

**Note:** Responses come from a constrained VAR(p) for all branches except those mentioned in the main text, in which an unrestricted VAR(p) model is used. The optimal lag length chosen on the basis of the sequential modified likelihood ratio (LR) test. For conciseness, only the quarterly aggregations of impulse responses are reported in the table. One/two/three asterisks mean a *p*-value (calculated by bootstrapping procedure) less than 10%, 5% and 1% respectively.

only increase 0.21% after one year of an unanticipated oil price increase. This relatively low pass-through can be explained (among others) by the fact that main energy source for industries seems not to be nowadays crude oil, but electricity and the gas.[25]

In contrast, there is no clear evidence about the transmission of such highest industrial prices to inflation at disaggregate level. The only exceptions to this are the *chemical* and *metal* branches, in which there is a significant transmission of prices in the channel oil-industry-consumption. These findings seem to confirm the results of other studies such as Álvarez et al. (2011), who show that this indirect transmission channel is limited.

[25] In the euro area (19 countries), gas makes up for 35.1% of final energy consumption, electrical energy 31%, solid fuels 11.5% and total petroleum products only 9.5%. In the US, electricity makes up 40.3% of energy use, natural gas 14.5%, unleaded gasoline 14%, diesel fuel 11.4% and jet fuel 9.7% (Kilian (2008)).

Table 4: Accumulated impulse responses of consumer price index (in percentages) attributed to a 1% oil price shock

| | branch | lags | quarter 1 | | quarter 2 | | quarter 3 | | quarter 4 | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | mining | 3 | 0.0053 | | 0.0106 | * | 0.0132 | * | 0.0146 | * |
| 2 | food | 2 | -0.0063 | | -0.002 | | 0.001 | | 0.0027 | |
| 3 | beverages | 7 | 0.0025 | | 0.0049 | | 0.0076 | | 0.0105 | * |
| 4 | tobacco | 9 | 0.0055 | | 0.0076 | | -0.0098 | | 0.0009 | |
| 5 | textile | 8 | -0.0013 | | -0.0015 | | -0.001 | | -0.0005 | |
| 6 | apparel | 4 | -0.0034 | | -0.0009 | | -0.003 | | -0.0026 | |
| 7 | leather | 6 | 0.0007 | | 0.0024 | | 0.0044 | | 0.006 | |
| 8 | wood | 12 | -0.0021 | | -0.0028 | | -0.0026 | | -0.0006 | |
| 9 | paper | 10 | -0.0023 | | -0.0025 | | 0.0014 | | 0.0055 | |
| 10 | recorded | 6 | -0.0029 | | -0.0042 | | -0.0062 | | -0.0073 | |
| 11 | chemical | 10 | 0.1626 | *** | 0.1598 | *** | 0.1443 | *** | 0.1599 | *** |
| 12 | non-metallic | 12 | -0.0004 | | -0.0003 | | 0.0006 | | 0.0029 | |
| 13 | basic metals | 11 | -0.0006 | | 0.0011 | | 0.0069 | | 0.0112 | |
| 14 | metal | 12 | 0.0029 | | 0.016 | *** | 0.0352 | *** | 0.0493 | *** |
| 15 | electronic | 6 | -0.0018 | | -0.006 | | -0.0052 | | -0.0059 | |
| 16 | electrical | 5 | 0.0008 | | -0.0001 | | 0.0003 | | 0.0008 | |
| 17 | machinery | 6 | -0.0016 | | -0.0052 | | -0.005 | | -0.0054 | |
| 18 | motor | 12 | 0.0018 | | 0.0012 | | 0.0031 | | 0.0061 | |
| 19 | transport | 7 | 0.0004 | | -0.0004 | | 0.0005 | | 0.0007 | |

**Note:** Responses come from a constrained VAR(p) for all branches except those mentioned in the main text, in which an unrestricted VAR(p) model is used. The optimal lag length chosen on the basis of the sequential modified likelihood ratio (LR) test. For conciseness, only the quarterly aggregations of impulse responses are reported in the table. One/two/three asterisks mean a $p$-value (calculated by bootstrapping procedure) less than 10%, 5% and 1% respectively.

# 5 Conclusions

The study of the transmission channels through which oil price changes affect macroeconomic variables is, in general, an interesting issue to better understand the consequences of oil price shocks and to design the optimal monetary policy for counteracting such effects. In particular, the analysis of how oil price shocks are transmitted downstream to producer and consumer prices at industrial level may be determinant for the design of such a policy.

This paper finds evidence of a partial oil price pass-through to producer prices for the branches with higher oil consumption and a negligible pass-through for the other branches. This result may be explained by the fact that crude oil has reduced its importance as a main energy source for the industries over the last two decades. Moreover, oil price pass-through to consumer prices is very low in general and is only relevant for two branches (*chemical* and *metal*). Therefore, we show evidence of some capacity of producers to adjust their production plans to changes in costs for most of the analyzed industrial branches, avoiding pass-through to consumer inflation. This is not the case for *chemical* and *metal*, where the pass-through from producer to consumer prices after an oil price shock seems to be almost complete.

The literature has found that oil price shocks reduce industrial production (see, e.g., Jiménez-Rodríguez [2008]), although the effects for each industry depend on the origin of the oil price changes (see, e.g., Fukunaga et al. [2010]). This paper sheds light on the possible explanations for the fall in the industrial production observed after an oil price shock in the related literature. This industrial production fall may be explained by the increase in producer prices (mainly for branches with higher oil consumption) after the oil shock and also by the adjustment in the production level for avoiding the transmission of higher costs to consumer prices.[26] Consequently, the design of the monetary policy reaction in the euro area should consider the fact that inflation risks do not seem to arise from supply shocks, but from the demand shocks.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[26]There are many factors that have been an important role in this adjustment. Some of these factors are the lower use of petroleum products in industrial production, technological innovations reducing industrial costs and the direct decision of producers in order to prevent the fall in the prices originated from the likely drop in future consumer demand.

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# Appendix

| | branch | NACE rev.2 | | COICOP/HICP | | weights* |
|---|---|---|---|---|---|---|
| 1 | mining | 8 | Other mining and quarrying | 0454 | Solid fuels | 0.151 |
| 2 | food | 10 | Manufacture of food products | 0111 | Bread and cereals | 2.603 |
| | | | | 0112 | Meat | 3.606 |
| | | | | 0113 | Fish and seafood | 1.076 |
| | | | | 0114 | Milk, cheese and eggs | 2.223 |
| | | | | 0115 | Oils and fats | 0.436 |
| | | | | 0116 | Fruit | 1.185 |
| | | | | 0117 | Vegetables | 1.575 |
| | | | | 0118 | Sugar, jam, honey, chocolate and confectionery | 0.940 |
| | | | | 0119 | Food products n.e.c. | 0.517 |
| | | | | 0121 | Coffee, tea and cocoa | 0.458 |
| 3 | beverages | 11 | Manufacture of beverages | 0122 | Mineral waters, soft drinks, fruit and vegetable juices | 0.920 |
| | | | | 0211 | Spirits | 0.327 |
| | | | | 0212 | Wine | 0.781 |
| | | | | 0213 | Beer | 0.592 |
| 4 | tobacco | 12 | Manufacture tobacco products | 022 | Tobacco | 2.374 |
| 5 | textiles | 13 | Manufacture of textiles | 0311 | Clothing materials | 0.035 |
| | | | | 0312 | Garments | 4.518 |
| | | | | 0313 | Other articles of clothing and clothing accessories | 0.213 |
| | | | | 0511 | Furniture and furnishings | 1.921 |
| | | | | 0512 | Carpets and other floor coverings | 0.125 |
| | | | | 052 | Household textiles | 0.457 |
| | | | | 0561 | Non-durable household goods | 1.021 |
| | | | | 0932 | Equipment for sport, camping and open-air recreation | 0.261 |
| 6 | apparel | 14 | Manufacture of wearing apparel | 0312 | Garments | 4.518 |
| | | | | 0313 | Other articles of clothing and clothing accessories | 0.213 |
| 7 | leather | 15 | Manufacture of leather and related products | 032 | Footwear | 1.222 |
| | | | | 0431 | Materials for the maintenance and repair of the dwelling | 0.419 |
| | | | | 052 | Household textiles | 0.457 |
| | | | | 054 | Glassware, tableware, household utensils | 0.528 |
| | | | | 0561 | Non-durable household goods | 1.021 |
| | | | | 0712 _0714 | Motor cycles, bicycles and animal drawn vehicles | 0.282 |
| | | | | 0932 | Equipment for sport, camping and open-air recreation | 0.261 |
| | | | | 1231 | Jewellery, clocks and watches | 0.463 |

**Note:** *We use the annual weights for each COICOP/HICP item from 2000 to 2014 published by Eurostat. To save space, we only report here the last available weights (2014 HICP basket).

| | branch | NACE rev.2 | | COICOP/HICP | | weights* |
|---|---|---|---|---|---|---|
| 8 | wood | 16 | Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials | 0431 | Materials for the maintenance and repair of the dwelling | 0.419 |
| | | | | 0511 | Furniture and furnishings | 1.921 |
| | | | | 052 | Household textiles | 0.457 |
| | | | | 054 | Glassware, tableware, household utensils | 0.528 |
| | | | | 055 | Tools and equipment, house and garden | 0.468 |
| 9 | paper | 17 | Manufacture of paper and paper products | 0431 | Materials for the maintenance and repair of the dwelling | 0.419 |
| | | | | 0561 | Non-durable household goods | 1.021 |
| | | | | 0931 | Games, toys and hobbies | 0.536 |
| | | | | 0953 _0954 | Miscellaneous printed matter; stationery and drawing materials | 0.325 |
| 10 | recorded | 8 | Printing and reproduction recorded media | 0953 _0954 | Miscellaneous printed matter; stationery and drawing materials | 0.325 |
| 11 | chemical | 20 | Manufacture of chemicals and chemical products | 0431 | Materials for the maintenance and repair of the dwelling | 0.419 |
| | | | | 0561 | Non-durable household goods | 1.021 |
| | | | | 0722 | Fuels and lubricants for personal transport equipment | 4.444 |
| | | | | 0914 | Recording media | 0.204 |
| | | | | 0931 | Games, toys and hobbies | 0.536 |
| | | | | 0933 | Gardens, plants and flowers | 0.604 |
| | | | | 0953 _0954 | Miscellaneous printed matter; stationery and drawing materials | 0.325 |
| | | | | 1212 _1213 | Electrical appliances for personal care; other appliances, articles and products for personal care | 1.704 |
| 12 | non-metallic | 23 | Manufacture of other non-metallic mineral products | 0431 | Materials for the maintenance and repair of the dwelling | 0.419 |
| | | | | 0511 | Furniture and furnishings | 1.921 |
| | | | | 0531 _0532 | Major household appliances whether electric or not and small electric household appliances | 0.891 |
| | | | | 054 | Glassware, tableware, household utensils | 0.528 |
| | | | | 1232 | Other personal effects | 0.425 |
| 13 | basic metals | 24 | Manufacture of basic metals | 0561 | Non-durable household goods | 1.021 |

**Note:** *We use the annual weights for each COICOP/HICP item from 2000 to 2014 published by Eurostat. To save space, we only report here the last available weights (2014 HICP basket).

| | branch | NACE rev.2 | | COICOP/HICP | | weights* |
|---|---|---|---|---|---|---|
| 14 | metal | 25 | Manufacture of fabricated metal products, except machinery and equipment | 0313 | Other articles of clothing and clothing accessories | 0.213 |
| | | | | 0431 | Materials for the maintenance and repair of the dwelling | 0.419 |
| | | | | 0452 | Gas | 2.100 |
| | | | | 0511 | Furniture and furnishings | 1.921 |
| | | | | 0531 _0532 | Major household appliances whether electric or not and small electric household appliances | 0.891 |
| | | | | 054 | Glassware, tableware, household utensils | 0.528 |
| | | | | 055 | Tools and equipment, house and garden | 0.468 |
| | | | | 0561 | Non-durable household goods | 1.021 |
| | | | | 0931 | Games, toys and hobbies | 0.536 |
| | | | | 0932 | Equipment for sport, camping and open-air recreation | 0.261 |
| | | | | 0953 _0954 | Miscellaneous printed matter; stationery and drawing materials | 0.325 |
| | | | | 1212 _1213 | Electrical appliances for personal care; other appliances, articles and products for personal care | 1.704 |
| 15 | electronic | 26 | Manufacture of computer, electronic and optical products | 055 | Tools and equipment, house and garden | 0.468 |
| | | | | 0721 | Spare parts and accessories for personal transport equipment | 0.554 |
| | | | | 0820 | Telephone and telefax equipment | 0.208 |
| | | | | 0911 | Equipment for the reception, recording and reproduction of sound and picture | 0.439 |
| | | | | 0912 | Photographic and cinematographic equipment and optical instruments | 0.122 |
| | | | | 0913 | Information processing equipment | 0.494 |
| | | | | 0914 | Recording media | 0.204 |
| | | | | 0931 | Games, toys and hobbies | 0.536 |
| | | | | 0953 _0954 | Miscellaneous printed matter; stationery and drawing materials | 0.325 |
| | | | | 1231 | Jewellery, clocks and watches | 0.463 |
| | | | | 1232 | Other personal effects | 0.425 |
| 16 | electrical | 27 | Manufacture of electrical equipment | 0511 | Furniture and furnishings | 1.921 |
| | | | | 0531 _0532 | Major household appliances whether electric or not and small electric household appliances | 0.891 |
| | | | | 055 | Tools and equipment, use and garden | 0.468 |
| | | | | 0721 | Spare parts and accessories for personal transport equipment | 0.554 |
| | | | | 0911 | Equipment for the reception, recording and reproduction of sound and picture | 0.439 |
| | | | | 0931 | Games, toys and hobbies | 0.536 |

**Note:** *We use the annual weights for each COICOP/HICP item from 2000 to 2014 published by Eurostat. To save space, we only report here the last available weights (2014 HICP basket).

| | branch | NACE rev.2 | | COICOP/HICP | | weights* |
|---|---|---|---|---|---|---|
| 17 | machinery | 28 | Manufacture of machinery and equipment n.e.c. | 0531 _0532 | Major household appliances whether electric or not and small electric household appliances | 0.891 |
| | | | | 054 | Glassware, tableware, household utensils | 0.528 |
| | | | | 055 | Tools and equipment, use and garden | 0.468 |
| | | | | 0721 | Spare parts and accessories for personal transport equipment | 0.554 |
| | | | | 0913 | Information processing equipment | 0.494 |
| | | | | 0921 _0922 | Major durables for indoor and outdoor recreation including musical instruments | 0.293 |
| 18 | motor | 29 | Manufacture of motor vehicles, trailers and semi-trailers | 0511 | Furniture and furnishings | 1.921 |
| | | | | 0711 | Motor cars | 3.162 |
| | | | | 0712 _0714 | Motor cycles, bicycles and animal drawn vehicles | 0.282 |
| | | | | 0721 | Spare parts and accessories for personal transport equipment | 0.554 |
| | | | | 0921 _0922 | Major durables for indoor and outdoor recreation including musical instruments | 0.293 |
| 19 | transport | 30 | Manufacture of other transport equipment | 0712 _0714 | Motor cycles, bicycles and animal drawn vehicles | 0.282 |
| | | | | 0721 | Spare parts and accessories for personal transport equipment | 0.554 |
| | | | | 0921 _0922 | Major durables for indoor and outdoor recreation including musical instruments | 0.293 |
| | | | | 0932 | Equipment for sport, camping and open-air recreation | 0.261 |
| | | | | 0934 _0935 | Pets and related products; veterinary and other services for pets | 0.654 |
| | | | | 1232 | Other personal effects | 0.425 |

**Note:** *We use the annual weights for each COICOP/HICP item from 2000 to 2014 published by Eurostat. To save space, we only report here the last available weights (2014 HICP basket).