# Dutch disease in the Norwegian agricultural sector. Exploring the oil price–food security nexus

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# Dutch Disease in the Norwegian Agricultural Sector

## Exploring the Oil Price — Food Security Nexus

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**Abstract**

Applying and augmenting the theoretical framework of the Dutch Disease, this paper investigates potential negative effects from the petroleum industry in Norway on agricultural profitability, and implicitly on food security due to the farmland abandonment effect. Two fundamental transmission channels of the oil price with an impact on agricultural profitability are analysed by vector equilibrium correction models: (1) The impact on producer prices, which affect input prices and then the costs of production; (2) The impact on food imports via the import-weighted exchange rate. A third channel is the wage differential in the respective sectors. Arguably, further consequences of low profitability and less farmland area is an increased pressure to become more efficient, which may result in increased use of antibiotics and increased depletion of soil. Therefore, due to the natural limits of boosting efficiency in biological systems and the farmland abandonment effect, Dutch Disease in the agricultural sector is generally more serious than in the classical deindustrialisation case.

**Keywords**: Food security, Agricultural Dutch Disease, Farmland Abandonment.

# 1 Introduction and background

According to the The Food and Agriculture Organization of the United Nations (FAO)[1], climate change and desertization threaten our ability to ensure global food security, eradicate poverty and achieve sustainable development. The FAO projects that food production will need to increase by 70% by 2050 to meet the world's food needs. Moreover the FAO projects that Africa will by 2030 lose two-thirds of its arable land if desertization is not stopped. Low self-sufficency and hence reliance on imported food for human or animal consumption thus appears to be increasingly risky in the future.

*Farmland abandonment* (FLA), which can be defined as land which ceases to be used for food production, actually poses a problem with the same effect as desertization and use of farmland for housing or public infrastructure. In a recent EU report, Terres et al. (2013) conclude that profitability in agriculture is one of the main drivers of FLA: "farm income plays a prominent role in the farmer's strategy regarding land use" (p. 14). Since farmland needs to be maintained regularly in order to be productive, FLA implies immediate reductions of productive capacity and self sufficiency of food. *It follows that factors which have a negative impact on agricultural profitability also contribute to FLA, and therefore have a negative impact on food security.*

It is well established empirically that booming sectors, typically related to the production and exports of oil, have a negative impact on other sectors such as traditional export industry and agriculture. This phenomenon is called Dutch Disease (hereafter DD, see section 2 for a review of the basic tenets of the DD theory). The research problem in this paper is thus to analyse to what extent the oil sector, due to the DD mechanism, might pose a threat to food security in an oil exporting country, using Norway as the object of study.

Food security involves not only quantity but also quality. It follows that less available farmland, whether it is due to FLA, climate change or any other reason, increases the pressure on the remaining farmland as well as on the livestock to become more efficient and productive. This increases the risk of soil depletion and increased use of medication such as antibiotics. There is already an extensive use of antibiotics in many countries, which in turn leads to the development of antibiotic resistent bacteria. According to the World Health Organization[2] (WHO), antibiotic resistance "is one of the biggest threats to global health, food security, and development today".

An analysis of the issue of food quality is outside the scope of this paper. As background information concerning our object of study as well as to highlight what is at stake, it is however warranted to mention a few facts. Among European countries Norway has very low use of antibiotics in the agricultural sector, according to the The European Medicines Agency[3] (EMA). For this reason alone it is desirable to increase domestic production and selv-sufficiency. However, Norway has little cultivated land compared to other countries, where

[1]FAO (2019)
[2]WHO (2018)
[3]EMA (2018)

only about 3.1% or 10,000 square kilometers of the total area is cultivated farmland. There is a reserve of about 12,000 square kilometers, of which the major part can only be used for grass. Less than 2% is suitable for food grains, and only 30% of the cultivated area is suitable for food grains, which is lower than any EU-country[4]. Since World War 2 about 1,200 square kilometers of farmland have been reallocated, primarily for housing, roads and railways. Still the total farmland area has increased somewhat, but the best parts suitable for food grains, potatoes and vegetables have been reduced. Moreover, about 35% of the arable reserve is swamp[5], which is subject to restrictions on its cultivation due to the fear of CO2 emissions. All in all, this means that food security (with respect to quantity, not quality) is relatively low in Norway, justifying the need for a stronger focus on FLA and mechanisms that may enhance the reallocation of farmland, such as DD in the agricultural sector. The DD-FLA problem however, is likely universal, and not restricted to Norway only.

The research design consists of two separate parts: i) a theoretical conceptual construct; ii) an empirical analysis using time series data. In the first part, using classical deductive reasoning, a causal chain linking the oil price to food security via profitability is proposed. The structure is *if $p$ then $q$*, where $p$ is the premise and $q$ is the consequent.

In the second part the validity of the premises are assessed, applying time series econometrics (cointegration) and general statistical techniques. Based on economic theory two relations (premises) stand out as particularly interesting, namely the relations between the oil price and 1) producer prices; 2) the import weighted exchange rate. These relations are considered transmission channels of the DD effect from the oil price to agriculture. To the best of my knowledge there is no previous research on the quantification of the effect on food imports from the oil exporting sector. We thus add to the literature by identifying another DD effect: the food imports effect. This effect is clearly related to the classical spending effect, and is generally described in economic theory as the import propensity, that is how much import increases when income increases. Our estimated long-run equilibrium relations can thus be labeled the oil price elasticity of food imports, measuring the percent change in the quantity of imports per percent change in the oil price.

The rest of the article is organized as follows. Section 2 presents the theoretical basis of DD and reviews selected literature. In this section the theoretical construct underlying the claimed link between the oil industry and food security is presented. The methodological part in section 3 starts with an explicit statement of the research question. Then the econometric method of cointegration is explained. This method is suitable for analysing the long-run equilibrium relations which constitute the essential premises in the theoretical construct. Section 4 displays the statistical results, and section 5 discusses, concludes and suggests topics for further research.

[4]Government of Norway (2019).
[5]Government of Norway (2019).

# 2 Theoretical framework and literature review

## 2.1 Dutch Disease: a general framework

The phenomenon of Dutch Disease, a term originating from the negative experiences in The Netherlands in the late 1970s, describes the causal relationship between a booming sector and the decline of other sectors such as traditional industry and agriculture. DD is defined as follows in the Financial Times Lexicon (2019):

> "Dutch disease is the negative impact on an economy of anything that gives rise to a sharp inflow of foreign currency, such as the discovery of large oil reserves. The currency inflows lead to currency appreciation, making the country's other products less price competitive on the export market. It also leads to higher levels of cheap imports and can lead to deindustrialisation [...] The origin of the phrase is the Dutch economic crisis of the 1960s following the discovery of North Sea natural gas."

The concept of the DD is well established in economic theory, not least due to the framework of (Corden and Neary, 1982, hereafter CN), where two fundamental effects are identified:

1. **The resource movement effect**: "The boom in the energy sector raises the marginal products of the mobile factors employed there and so draws resources out of other sectors, giving rise to various adjustments in the rest of the economy... ." (CN p. 827.)

2. **The spending effect**: "The higher real income resulting from the boom leads to extra spending on services which raises their price (i.e. causes a real appreciation) and thus leads to further adjustments. [...] [T]he importance of this effect is positively related to the marginal propensity to consume services." (CN pp. 827—828.)

The literature on DD is substantial. Prominent examples besides the aforementioned CN are Bruno and Sachs (1982), Eastwood and Venables (1982) and Corden (1984). Typical findings are that a booming natural resource-exploiting sector has a negative impact on the traditional tradable industry sector, and a positive impact on the non-tradable service sector. Agriculture is affected negatively to the extent that this sector is tradable on the world market. Regarding effects on agriculture specifically, most of the research seems to be from Asia and Africa, where the results generally support the predictions from the CN framework. For example, using panel cointegration Abdlazis et al. (2018) investigate the long-run relationship between the oil price and agriculture in 25 developing oil-exporting countries. They find that there are significant negative effects of the real oil price and the exchange rate on agriculture value added, which they claim indicate DD and deagriculturalisation in oil-exporting economies. Apergis et al. (2014) also apply panel cointegration in their investigation of the effect of oil rents on agriculture value added in oil producing countries from the Middle East and North Africa. They find a negative long-run relationship between oil rents and value added in the agricultural sector, and with slow equilibrium adjustment. Their results, they claim, are consistent with a *contraction in the agricultural sector in the long-run* due to the negative impact from the oil sector.

One relevant article from Norway on classical DD is Røed Larsen (2006), asking whether Norway is escaping the resource curse. He concludes that Norway did escape the curse during the 1980s, but that there were a structural break in the 1990s. His data material indicates a rapid slow down of growth in 1999 - 2002. This stagnation he suggests (p. 636),"may be the result of a late onset of a curse and a disease". He also warns that politicians "may purchase political power in elections by extending to special interests generous promises of using oil revenues. When they keep such promises, excess demand may arise, which creates real appreciation, loss of competitiveness, de-industrialization, and both the curse and the disease." Røeds's article is thus in agreement with the general findings in the present article. It does not mention Norwegian agriculture however, which, to the best of my knowledge no other papers do.

## 2.2 Profitability channels

### 2.2.1 Producer prices

In Norway financial support to the Norwegian agriculture is negotiated annually between the government and the Budget Committee for Agriculture and Farming, hosted by the research organization NIBIO. To the best of my knowledge there is however no specific statistics or literature on the relationship between the oil price and profitability in the agricultural sector. The extent to which farmers are systematically and specifically compensated for costs due to increased producer prices is therefore uncertain, and is left as a topic for further research.

### 2.2.2 Exchange rates and imports

In floating exchange rate regimes the exchange rate (the currency price) is determined by the supply of and demand for a country's currency. An important determinant is the trade balance, which measures the difference between the values of exports and imports. A positive balance, that is when the value of exports exceeds the value of imports, generates excess demand for the currency of the exporting country (this occurs when the exporting company changes the income in foreign currency to the domestic currency). This excess demand, in accordance with economic theory, normally increases the price of the currency (a currency appreciation).

For an oil exporting country like Norway the price of oil increases the value of its oil exports, which contributes to a positive trade balance and increased demand for the Norwegian krone. Hence, rising oil prices are associated with an appreciation of the oil exporting country's currency.

Between 1992 and 2001 Norway had a mixture of a fixed and a flexible exchange rate regime. The target was to keep the Norwegian krone stable versus a basket of currencies, though without central bank intervention (purchasing or selling currency) if the Norwegian krone deviated from a targeted exchange rate relative to a basket of currencies. Instead the central bank used the interest rate (hence the contradictory label "flexible fixed" regime). For example, if the demand for the Norwegian krone was low, the central bank increased the interest rate in order to increase the demand for the krone. In 2001 Norway introduced a flexible inflation targeting floating exchange rate regime, where the central bank follows an explicit target for the price level in the country. The central bank attempts to control aggregate demand, and then inflation, by lowering or raising interest rates, depending on whether the inflation rate is above or below a prespecified target. In a flexible inflation targeting framework, both the output level as well as the level of unemployment is given some emphasis in addition to the inflation level when the interest rate level is determined. The following selected papers show a mixed picture with respect to the oil price effect on the value of the Norwegian krone. Reasonably this is a result of the previous currency regimes.

Bjørk et al. (1998), using cointegration analysis on data from 1979 to 1997, find a clear tendency of depreciation in the Norwegian krone after an enduring fall in the oil price, but that this tendency is strongly influenced by the incidents in the international oil market in 1985-86. However, for temporary swings in the oil price, the authors state that it appears that the central bank has been able to neutralize the effect on the exchange rate.

Bjørnstad and Jansen (2006) find that rising oil prices coincide with "some appreciation" of the Norwegian krone in the short-term. However, they have not been able to establish a clear long term effect on the exchange rate from the oil price (the oil price coefficient had low statistical significance).

Akram (2006) states that previous empirical studies have suggested an ambiguous relationship between crude oil prices and exchange rates. When exploring a non-linear relationship between these variables, he reveals a negative relationship when "oil prices are below 14 dollars and are falling" (p. 476).

In the present paper, when using data from the flexible inflation targeting regime only, the oil price effect is unambiguous, showing that the Norwegian krone appreciates when the oil price rises.

### 2.3 Conceptual construct: The oil price — food security nexus

The following presents a theoretical model of the channels through which the price of oil and the wealth from it can affect the profitability in the agricultural sector, and then on FLA and food security. The end of the model is the conditional statement $rising\ oil\ prices \rightarrow reduced\ food\ security$, where $rising\ oil\ prices$ is the premise, and $reduced\ food\ security$ is the consequent. To arrive at this end we apply propositional logic (the law of syllogism), where several conditional statements are combined. The general form is:

1. $p \rightarrow q$
2. $q \rightarrow r$
3. Therefore $p \rightarrow r$.

The conditional statements are shown in the flow diagram in Figure 1. For example, in the leftmost branch, starting with the relationship between the oil price and producer prices, the construction of the syllogism is demonstrated.

1. $Rising\ oil\ prices \rightarrow rising\ producer\ prices.$
2. $Rising\ producer\ prices \rightarrow rising\ factor\ costs\ in\ agriculture.$
3. $Rising\ factor\ costs\ in\ agriculture \rightarrow reduced\ profitability\ in\ agriculture.$
4. $Reduced\ profitability\ in\ agriculture \rightarrow reduced\ employment\ in\ agriculture.$ (A resource movement effect.)
5. $Reduced\ employment\ in\ agriculture \rightarrow farmland\ abandonment.$
6. $Farmland\ abandonment \rightarrow reduced\ food\ security.$
7. Therefore $rising\ oil\ prices \rightarrow reduced\ food\ security.$

The other two branches follow the same logic, which gives us the final conditional result. It is important to note that, since the premises are constituted by *stochastic time series variables*, the conditional statements are expressed in terms of expectations, i.e. as average long-run relationships. Note also that if oil revenues in certain ways are funnelled into the agricultural sector such that the negative effects are neutralized, the causal chain is automatically broken.

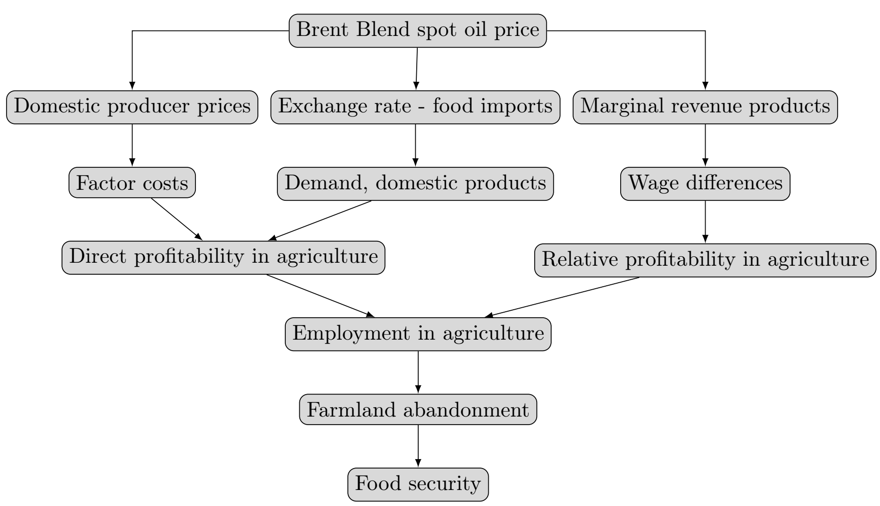



Figure 1: The oil price – food security nexus

We can split the oil price effects into direct and relative effects, where the relative profitability effect is constituted by the average wage differential between the petroleum sector and other sectors. The wage differential is due to the higher marginal revenue product of labor (MRPL) in the oil sector. This is the additional revenue the oil sector can generate by hiring one additional unit of labour. The MRPL is the product of i) the marginal product of labor (MPL) – the amount of additional output one additional worker can generate – and ii) the sales price of output. Direct effects are those impacting agricultural profitability (producer price and exchange rate effects) directly.

Note that the theoretical model assumes that the classical effects are not independent of each other: anything that affects direct and relative profitability in the agricultural sector, affects resource movement, and hence FLA and food security. One example is the impact of the oil price on the exchange rate. When the oil price rises the exchange rate appreciates, and foreign goods and services become cheaper to citizens in the oil exporting country. This is an income effect which increases imports and then reduces demand for domestically produced goods and services. The effect on profitability in the impacted sector, in this case the agricultural sector, is likely to be negative, which in turn impacts demand for labour (the resource movement effect) in the agricultural sector negatively. On the other hand, imported input factors becomes cheaper. However, rising and persistently high oil prices seem to have been the principal characteristic, such that the net effect is likely negative for agricultural profitability.

# 3 Method

## 3.1 Research questions

Before describing the research method, we formulate explicitly the main research questions as follows:

1. Do stable long-run equilibrium relations between the fundamental premises exist? I.e. between the oil price and (i) producer prices, (iia) exchange rates and (iib) food imports[6], (iii) imports and the exchange rate, and iv) resource movement in agriculture (measured by hours worked).

2. Do proper equilibrium adjustment in the endogenous variables take place? See section 3.3 for explanation of adjustment properties.

## 3.2 Data

All data are quarterly time series observations except for those in the oil price – producer price model, which are monthly. The following variables have been used.

- *Hours worked* in the following sectors. Source: SSB (2019a).

[6]This relationship is measured graphically and by correlations, and does not enter into the econometric model.

  - Agriculture
  - Petroleum
  - Hotels and accommodation services.
  - Traditional industry.
  - Construction (housing).
  - Business services.

- The spot price of Brent Blend oil (monthly and quarterly data). Source: Federal Reserve Bank of St. Louis (2019).
- Norwegian producer prices (monthly data). Sources: SSB (2019c) and author's calculations.
- The Norwegian import-weighted exchange rate. Source: Norges Bank (2019).

The observation periods are primarily restricted only by the availability of the data. For quarterly data the sample ranges from 1995Q1 to 2018Q3. Monthly data are available from 2000M1 to 2018M6. Due to disturbances in the data before the financial crisis, which cause heteroscedasticity in the variance of the residuals, the oil price - producer price model uses more recent data, starting in 2008M1.

### 3.3 Eonometric analysis: The vector equilibrium correction model

A general description of the method is as follows. Let $\{x_t\}_{t:T} = \{x_{1t}, x_{2t}, ..., x_{nt}\}'_{t:T}$ be a time series vector of $n$ variables observed from time $t = 1$ to $t = T$. A vector equilibrium correction (VEC) model for the change in $x_t$, $(\Delta x_t)$ is given by Equation 1.

$$\Delta x_t = A_0 + \Pi x_{t-1} + \sum_{k=1}^{p-1} \Gamma_k \Delta x_{t-k} + v_t. \tag{1}$$

$A_0$ is an $n \times 1$ vector of constant terms, $\Gamma_k$ is an $n \times n$ coefficient matrix multiplying the lagged first differences, $\Pi$ is an $n \times n$ coefficient matrix multiplying the lagged levels, $v \sim N[0, \Omega]$ are *iid* error terms, and $\Omega$ is an $n \times n$ positive definite covariance matrix. There are $p$ lags in the underlying unrestricted vector autoregression (VAR) model, but only $p - 1$ lags in the re-parameterized VEC model, i.e. the VAR with cointegration restrictions.

In the Johansen method[7] applied in this paper, the existence of cointegrating relations can be inferred from the rank of $\Pi$. If this number is less than the number of rows (or columns), corresponding to the number of variables in the system, we say that the matrix has reduced rank. The rank $r$ may be

[7] See Johansen (1996)

- $r = n$: $\Pi$ has full rank. In this case, all variables in $x_t$ are stationary in levels. Thus it is appropriate to estimate the system as a VAR in levels, and standard inference (hypothesis testing) is valid for this system since it is stationary. This is also equivalent to saying that all variables in the model are stationary (i.e. integrated of order zero, or I(0)). A VAR model can thus validly be estimated equation by equation using ordinary least squares, without any transformations or restrictions.

- $r = 0$: $\Pi$ has zero rank. In this case, all eigenvalues of $\Pi$ are equal to zero, $\Pi$ consists of zeros, and each variable is nonstationary. Provided that all variables have one unit root in the characteristic equation (i.e. I(1) variables), we should estimate a VAR in first differences in this case.

- $0 < r < p$: $\Pi$ has reduced rank. In this case, we have cointegration, and the number of stationary long-run equilibrium relations is equal to the rank of $\Pi$, which is equal to the number of nonzero eigenvalues of $\Pi$. Now it will be possible to write a row (column) of $\Pi$ as a linear combination of other rows (columns).

The long run equilibrium relationships are contained in $\Pi$ of rank $r$. $\Pi$ can be decomposed into a product of two new matrices $\alpha$ and $\beta$:

$$\Pi = \alpha\beta', \tag{2}$$

where $\alpha$ is an $n \times r$ matrix of adjustment coefficients, and $\beta$ is an $n \times r$ matrix of cointegrating coefficients (also called long-run proportionality constants). The whole system, cf. Equation 1, is estimated by the method of Johansen, see for example Johansen (1996) or Juselius (2006) for excellent expositions.

**A note on seasonality**

Cointegration means that variables tend to either follow each other or to move inversely relative to each other. If $\beta > 0$ the variables follow each other up and down, i.e. a positive relationship; if $\beta < 0$ thee is a negative relationship and the variables move inversely relative to each other. In both cases we say that the variables have common trends. However, it may be the case that the common trends are due to co-movement in some of the seasonal components of the variables. If so, depending on the statistical properties of the seasonal components, this may impact on the choice of estimation method. If the seasonal components are nonstationary (i.e. containing unit roots in their characteristic equations), so-called seasonal cointegration should be applied. If the seasonal components on the other hand exhibit stationary behaviour it is appropriate to include seasonal dummy variables in the model. These dummy variables then account for variations in the means of the respective variables, and then contribute to whitening of the model residuals. In the present paper it is assumed that the variables have stationary seasonal components, and seasonal dummy variables have thus been included. This assumption rests on the evidence from the Canova and Hansen (1982) and Hylleberg et al. (1990) tests combined with graphical inspection of the trend – seasonal decompositions of the variables.

### 3.3.1 Choice of lag length in the underlying VAR model

There is no unique bullet proof method available for determination of the number of lags to include in the unrestricted VAR. A popular method is to use so-called information criteria. These are based on maximization of the likelihood function, and there is a penalizing factor for each extra lag added in order to avoid over-parameterization and loss of degrees of freedom. The drawback of this method is that different information criteria (for example Akaike, Schwarz or Hannan-Quinn) often suggest different optimal lag lengths. And when information criteria do not agree, "[h]ow should we proceed?" asks Juselius (2006, p. 72). Moreover, this method is valid only when the model itself is correctly specified, see Juselius (2006, p. 71). Thus, according to Juselius (2006, p. 72), "[...] if there are other problems with the model, [...] then these should be accounted for prior to choosing the lag length."

A typical problem in time series analysis is autocorrelated residuals, which presence in dynamic models make parameter estimators inconsistent. The standard advice is to increase the lag length in order to 'cure' autocorrelation. According to Juselius (2006, p. 72), "[t]he question is whether it is advisable to increase the lag length at this stage. Since other types of misspecification, such as outlier observations and mean shifts, are likely to generate autocorrelated residuals, the lag tests will often suggest too many lags in a model which suffers from such misspecification. But to be able to diagnose the source of misspecification we need to determine the lag length, and to determine the lag length we need a well-specified model." Thus, tests of lag length specification and misspecification depend on each other. Juselius (2006, p. 72) concludes that "even if it is difficult to give a precise rule for how to proceed, experience suggests that adding too many lags is more harmful for the results than accepting some moderate residual autocorrelation in the model." Her general advice is that it is seldom the case that a well-specified model needs more than two lags.

The founder of the Johansen method, Sören Johansen, treats lag length determination in his textbook (Johansen, 1996, p. 21). He states that: "It is our experience that if a long lag length is is required to get white noise residuals then it often pays to reconsider the choice of variables [...]. That is, rather than automatically increase the lag length, it is more fruitful in a multivariate context to increase the information set. The methods that will be derived in the subsequent chapters are based upon the time independence of the residuals, hence an important criterion for the choice of lag length is that the residuals are uncorrelated."

This advice of Johansen and Juselius has been followed in this paper. We can also add the principle of parsimony. Long lag lengths consume degrees of freedom, which reduces the precision of the estimators. Since large outliers and seasonal mean shifts are likely to cause both autocorrelation as well as heteroscedasticity in the residuals, impulse and seasonal dummy variables have been included where needed. The model residuals then become satisfactory, and it is assumed that the models are well-specified.

### 3.3.2 Adjustment coefficients and long-run causality

According to Juselius (2006, p. 193)[8], "tests on $\alpha$ are closely associated with interesting hypotheses about the common driving forces of the system. The test of a zero row in $\alpha$ is the equivalent of testing whether a variable can be considered weakly exogenous for the long-run parameters $\beta$." Thus, if the adjustment coefficient in, say, the $\Delta x_{1t}$ equation is not significantly *different* from zero, then $x_{1t}$ defines a *common driving trend*, consisting of the sum of the empirical shocks to this variable. Variables with adjustment coefficients significantly different from zero are said to be long-run weakly endogenous, which purely adjust to shocks in the exogenous variables.

Therefore, testing for long-run weak exogeneity *could identify pushing and pulling forces* of the system. However, the estimators of the adjustment coefficients depend on both the rank of $\Pi$ as well as on changes in the information set, for example by adding (or removing) variables. The classification of common driving trends is thus a weaker statistical result than the identification of equilibrium relations, since a common trend (i.e. cointegration) in a small model, with, say, two variables, does not disappear if we add more variables to the system. We expect that the price of oil, being determined on the world market, is long-run weakly exogenous in all models. Therefore the price of oil does not have a separate equation in the equilibrium correction models, but is included in the long-run equilibrium relations, and lags of first differences are included in the equations of the endogenous variables.

[8]Referring to Johansen (1996), chapter 8.

# 4 Results

## 4.1 Classical Dutch Disease

Table 1, comparing *hours worked* in selected sectors in 1995 and in 2018, is consistent with the resource movement effect in the Corden—Neary framework. Traditional sectors like agriculture and industry have declined, while the petroleum sector and the construction, business services and health sectors have grown. For example, hours worked in the agricultural sector in 2018 constituted only 48% of the level in 1995, while hours worked in the petroleum sector nearly doubled during the same period. Business services increased the most, reaching more than three times their 1995 level. Figure 2 shows a bar graph of *employment levels* in the same sectors (scientific and technological services added) in 1995 vs 2018, while Figure 3 displays the change in employment in percent. These graphs are consistent with hours worked in the respective sectors. The issue of technological change as a factor contributing to the decline in employment in the agricultural sector is discussed in section 4.2.2.

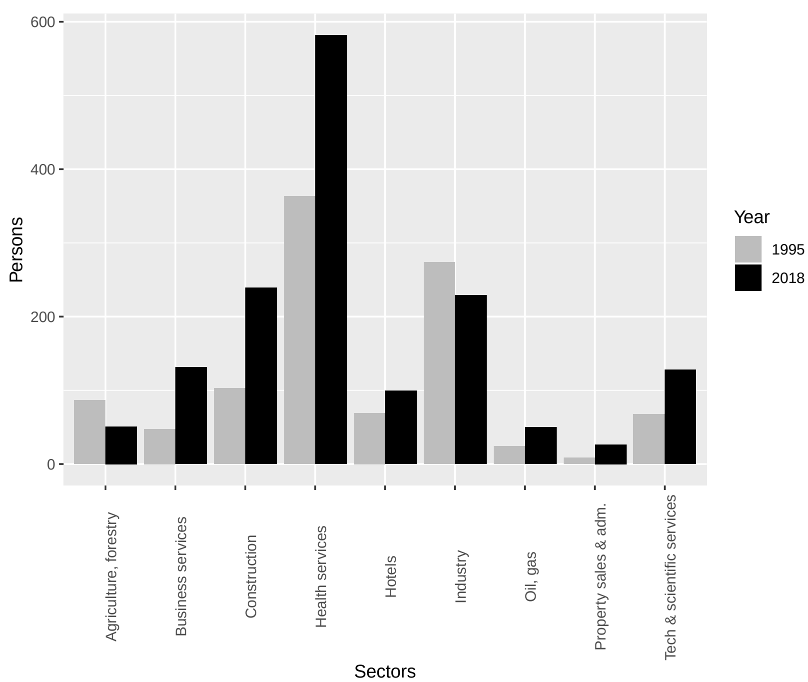



Figure 2: Employment (1000 persons) in selected sectors, 1995 - 2018.
Source: Statistics Norway. Author's calculations.

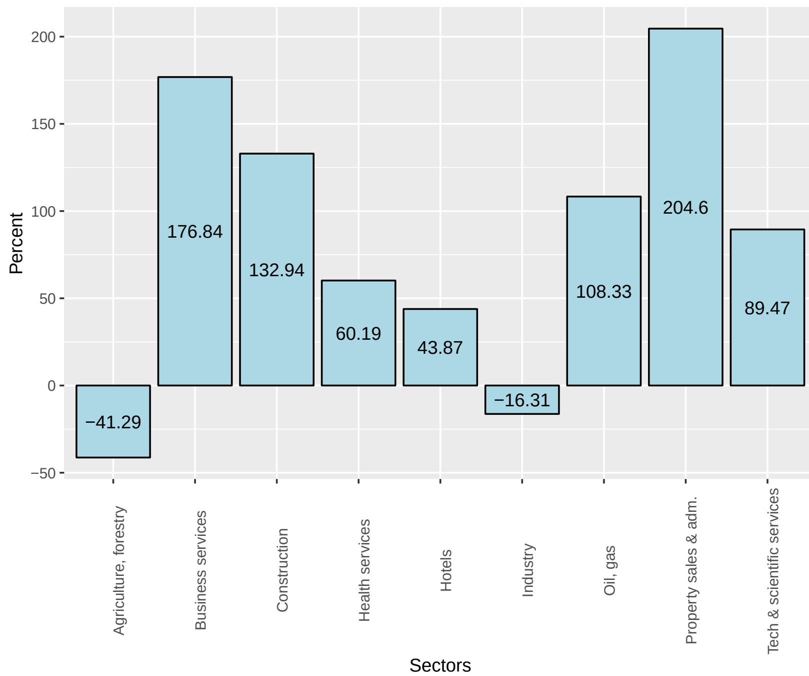



Figure 3: % change in employment in selected sectors, 1995 - 2018.
Source: Statistics Norway. Author's calculations.

Table 1: Hours worked, 1995 - 2018 (millions per quarter).

| Year | Agri | Petro | Industry | Constr. | Bus. serv. | Health | All |
|---|---|---|---|---|---|---|---|
| 1995 | 43.03 | 10.20 | 108.18 | 42.40 | 14.70 | 105.53 | 788.40 |
| 2018 | 20.60 | 19.73 | 86.20 | 93.43 | 48.73 | 177.13 | 985.37 |
| 2018/1995 | 0.48 | 1.93 | 0.80 | 2.20 | 3.32 | 1.68 | 1.25 |

Source: Statistics Norway. Author's calculations.

## 4.2 Dutch Disease in the agricultural sector

Having demonstrated that the data are consistent with the presence of DD in the Norwegian economy in general, we narrow the focus and look specifically at the agricultural sector.

### 4.2.1 Wage differentials

We start with an example of the relative profitability effect in agriculture vs the oil sector. The higher marginal revenue product in the oil sector, i.e. the additional revenue generated by hiring one additional employee, enables wages to be higher in the oil sector. This is likely to contribute to a resource (labour) movement effect from agriculture to the oil sector.

Table 2 shows a recent example of the average monthly wage rates for milk and meat producers versus machine operators in the petroleum sector. Note that there are large variations in agricultural income, and that other income sources are needed in many cases.

Table 2: Average monthly wage rate

| Year | Agriculture | Petroleum |
|---|---|---|
| 2015 | 3368 | 7138 |
| 2016 | 3292 | 6985 |
| 2017 | 3459 | 7300 |
| 2018 | 3624 | 7672 |

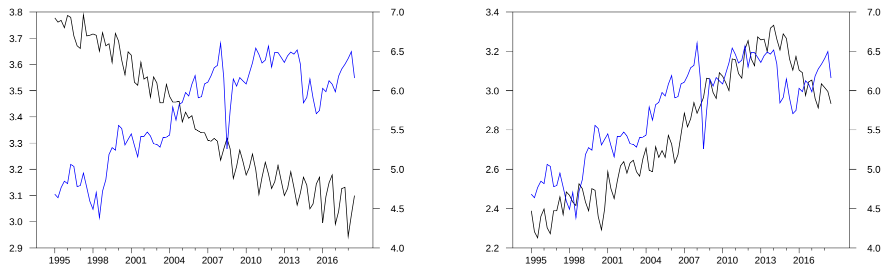
Note: Agriculture: Milk and meat producers. Petroleum: machine operators. Source: SSB (2019b).

#### 4.2.2 Equilibrium relations

The following section introduces the common trend analysis by the graphical method used to identify potentially stable long-run equilibrium relations. The relationships between price of oil and hours worked in the agricultural and petroleum sectors are used as examples. Figure 4 shows that hours worked in the agricultural sector is inversely related to the price of oil (panel (a)), and that hours worked in the petroleum sector is positively related to the price of oil (panel (b)). This implies that hours worked in the agricultural sector is inversely related to the hours worked in the petroleum sector. Note that the financial crisis in 2008 affected negatively both the price of oil and hours worked in both sectors. Exogenous incidents, such as the financial crisis, may therefore conceal an otherwise negative endogenous relationship between hours worked in the two sectors. In this case, however, the sample period is sufficiently long to prevent a dominating impact from the 2008 data.

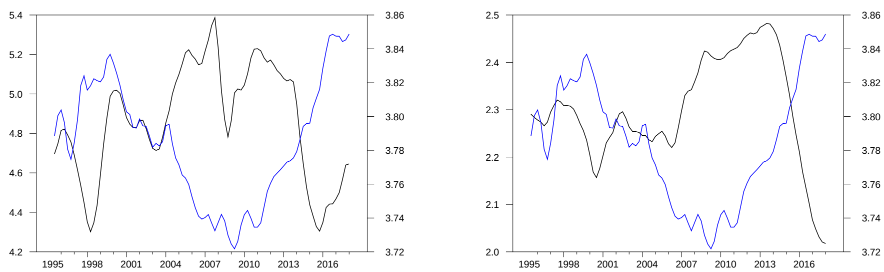
By removing the linear time trends and generating a 4 quarter moving average in order to smooth the series and remove noise, and possibly also the impact of *persistent* technological change, the medium term swings become more visible. Figure 5 thus provide evidence that the inverse relationship does not depend on the linear trends in the variables.

As noted above, in order to avoid spurious results, regression models with time series variables require that all variables are stationary, implying no unit roots in the characteristic equations of the variables. In general linear combinations of nonstationary variables are nonstationary, but in the special case of cointegration where linear combinations of nonstationary variables become stationary, standard statistical inference is valid, cf. the representation theorem of Engle and Granger (1987). This theorem states that if two variables are *cointegrated*, i.e. have a common stochastic trend, the correct choice is an equilibrium correction model (ECM). Now the variables obey a long-run equilibrium rela-




(a) (b)

Figure 4: Panel (a): Hours worked in the agricultural sector (black, left scale) vs. the Brent Blend oil price in NOK. Panel(b): Hours worked in the petroleum sector vs. the Brent Blend oil price in NOK. All variables are in natural logarithms.




(a) (b)

Figure 5: Detrended 4 quarter moving averages. Panel (a): The oil price in NOK (black, left scale) vs. hours worked in the agricultural sector. Panel (b): Hours worked in the oil sector (black, left scale) vs. hours worked in the agricultural sector. All variables are in natural logarithms.

tion, implying that deviations from equilibrium are corrected by real economic equilibrating forces.

**Seasonal properties of the time series**

The Canova and Hansen (1982) test clearly indicates that all variables but hours worked in the agricultural sector have stationary seasonal components (nonstationarity cannot be rejected for quarters 1, 3 and 4 for hours worked). However, according to the inspection of the seasonal decomposition, the latter clearly appears to be stationary also. It is thus assumed that nonstationarity in the seasonal components is not an issue, implying that we can safely use seasonal dummy variables in the models instead of seasonal cointegration.

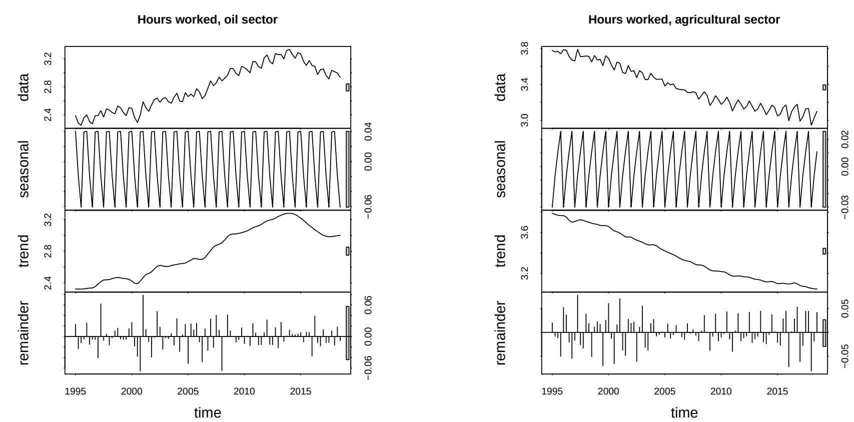
The stability of the seasonal components of hours worked in the agricultural sector is illustrated in Figure 6.[9]

[9]Similar figures for the remaining variables are available upon request.

Table 3: Joint Canova-Hansen test for seasonal stability.

| Variable | test stat | p-val |
|---|---|---|
| Oil price | 0.49 | 0.56 |
| Exchange rate | 0.65 | 0.41 |
| Food imports | 1.12 | 0.08 |
| Hours worked, oil | 0.68 | 0.38 |
| Hours worked, agri | 2.01 | 0.01 |
| Producer price | 1.87 | 0.38 |

Note: The joint test is an F-statistic encompassing all four seasons. Null hypothesis: stationarity.




(a) (b)

Figure 6: Panel (a): Hours worked in the oil sector. Panel (b): Hours worked in the agricultural sector. The variables are in natural logarithms.

The HEGY test is also carried out. This function computes the Hylleberg et al. (1990) statistics for testing the null hypothesis that seasonal unit roots exist, i.e. the opposite hypothesis of the Canova-Hansen test. In order for the two tests to be consistent with each other, non-rejection of stability in the Canova-Hansen test should produce rejection of nonstationarity in the HEGY test. For the import weighted exchange rate and food imports this is not the case for the first and second quarter. The same conclusion is reached for hours worked in the oil sector. This inconsistency is exemplified by the import weighted exchange rate in table 4. The tests are therefore inconclusive. In the face of this the best choice is to rely on the Johansen rank test for overall stationarity of the long-run relations. The alternative would be to guess whether and how seasonal cointegration exists, which appears hazardous in the present case.

Table 4: HEGY test for seasonal instability the import weighted exchange rate.

| Season | test stat | p-val |
|---|---|---|
| Q2 | 16.97 | 0.15 |
| Q1 | 12.73 | 0.15 |

Note: Null hypothesis: nonstationarity.

**The oil price - producer price premise**

Panel (a) in Figure 7 clearly indicates a positive long-run equilibrium relationship between the NOK denominated price of Brent Blend oil and the Norwegian producer price index.

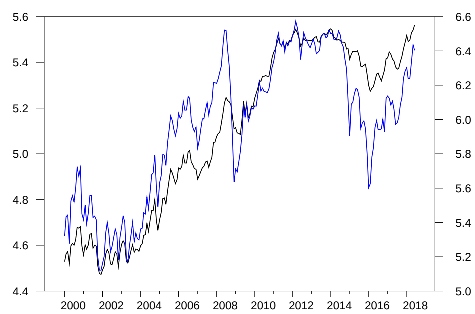



Figure 7: Norwegian producer price index (black, left scale) vs. Brent Blend oil price in NOK. Source: Statistics Norway.

The graphical evidence is supported by the Johansen rank test, which clearly rejects no cointegration ($p$-value $= 0.0082$). The test cannot reject one long-run equilibrium relation ($p$-value $= 0.3664$). Equation 3 shows the estimate of the positive long-run relationship, indicating that, on average a 0.44% rise in the producer price index (i.e. a long-run elasticity not far from 0.5) follows from a 1% rise in the price of oil. Table 6 shows the estimates of the coefficients for

Table 5: Rank test: PPI vs the price of Brent oil in NOK

| Rank | Eigenvalue | Trace test | p-value |
|---|---|---|---|
| 0 | 0,17993 | 31,496 | 0,0082 |
| 1 | 0,0075 | 6,8979 | 0,3664 |

the growth rates of the endogenous producer price index. There is a significant equilibrium correction, where about 9% of the equilibrium error in the previous period is corrected. In addition there is a positive reaction to lagged changes in the price of oil.

$$ppi_t = \underset{(7.895)}{0,441} lbrnok_t + \underset{(3.940)}{0,001} \, trend + u_t, \tag{3}$$

Table 6: Equation 1: $\Delta ppi_t$

| | Coefficient | Std. Error | $t$-ratio | p-value |
|---|---|---|---|---|
| const | 0.2493 | 0.0818 | 3.045 | 0.0029 |
| $\Delta$lbrnok$_{t-1}$ | 0.1745 | 0.0392 | 4.445 | 0.0000 |
| d0909 | −0.0829 | 0.0270 | −3.065 | 0.0028 |
| d0907 | −0.0795 | 0.0221 | −3.598 | 0.0005 |
| d1612 | 0.0673 | 0.0218 | 3.087 | 0.0025 |
| EC1 | −0.0960 | 0.0320 | −3.001 | 0.0033 |

There are three significant outlier dummy variables in this model: $d0907$, $d0909$, and $d1612$ are dummy variables, taking care of outliers $> 2,5$ standard deviations. Residual tests (see the appendix) are satisfactory with respect to autocorrelation and heteroscedasticity, but not with respect to normality. We therefore have to rely on the central limit theorem providing approximately normal estimators, such that statistical inference is approximately valid.

At a more specific level we can look at the relationship between the oil price and the important cost categories diesel, heating oil (for drying of grain) and lubricants. These data are available only on annual basis, and there are too few observations for any econometric analysis. Figure 8 shows that the fluctuations in these costs are determined by the fluctuations in the oil price.

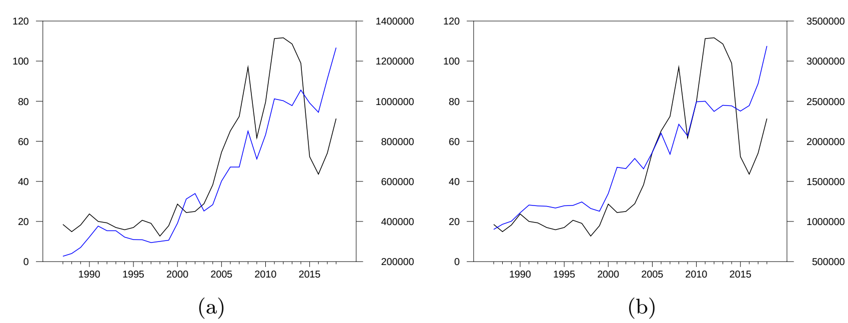



Figure 8: Panel (a): Brent Blend oil price (black, left scale) vs cost of diesel fuel. Panel (b): Brent Blend oil price (black, left scale) vs cost of lubricants.

Source: Statistics Norway.

**The oil price - exchange rate - food imports premise**

An inverse long-run relationship between the import weighted exchange rate and the oil price is indicated by Figure 9.

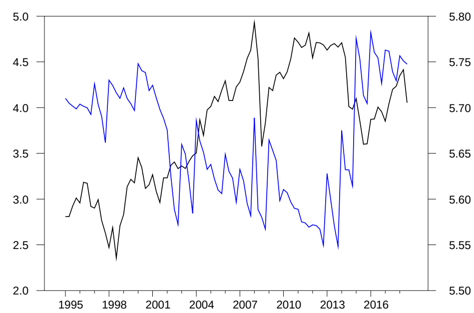



Figure 9: Import weighted exchange rate vs. Brent Blend oil price (black, left scale) . Source: Statistics Norway.

Figure 10 displays the pairwise relationships between the NOK/USD exchange rate, food imports, the import-weighted exchange rate, and the price of Brent Blend oil. All variables are *detrended*, in order to highlight the positive and negative relationships between the variables which are not due to any rising or falling tendencies in the long-run. First we note the very strong positive correlation between the NOK/USD exchange rate and the import-weighted exchange rate (0.735). This suggests that the price of oil may have a strong impact on the demand for imports: when the price of oil rises the import weighted exchange rate appreciates (i.e. the exchange rate falls, and Norwegians pay less per unit of foreign currency), and foreign goods become cheaper for Norwegian consumers. This is an income effect, and we thus expect the demand for imports to increase. This is exactly what happens. From Figure 11 panel (b) it is clear that when the import weighted exchange rate falls (appreciation) imports go up, which is reflected by the negative correlation between the import weighted exchange rate and imports (-0.46) and the corresponding downward sloping scatterplot in Figure 10. This relationship is further confirmed by the positive correlation between the price of oil and imports (0.385) and the corresponding upward sloping scatterplot in Figure 10.

We therefore see a clear candidate for an equilibrium correction relationship between the price of oil, the import-weighted exchange rate, and food imports. Since we now have three variables there may be two equilibrium relations.

The individual bivariate rank tests in Tables 7 and 8 confirms that these variables constitute pairwise stable equilibrium relationships (the food imports and exchange rate relation is significant at the 10% level), while table 9 confirms that none of the variables can be excluded from the long-run equilibrium (cointegration) relations. We therefore estimate a VECM with two equilibrium relations, in which the price of oil enters the equilibrium relations as an exogenous variable.

Equation 4 shows the (trend adjusted) oil price - import weighted exchange rate equilibrium relation, where the long-run elasticity is about $0,13$. In the (trend adjusted) food imports - import weighted exchange rate equation (Equa-

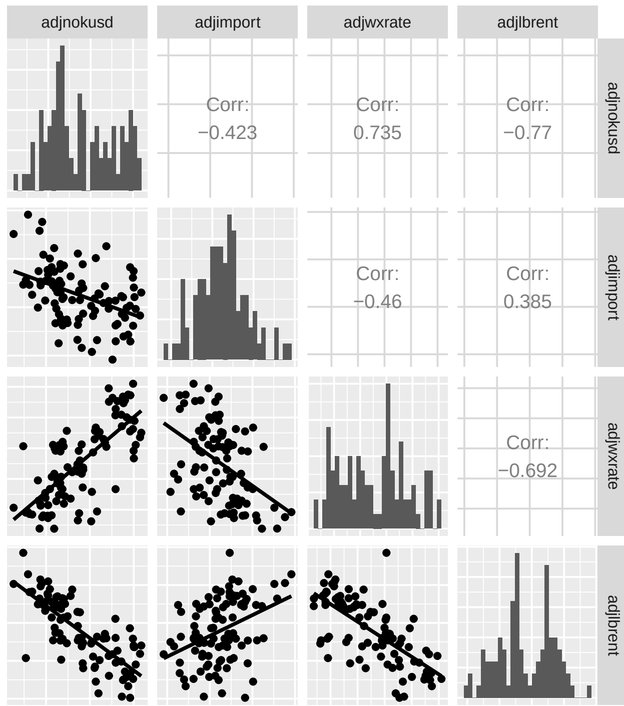



Figure 10: Detrended variables in logarithms, from left to right (top to bottom): NOK/USD exchange rate (adjnokusd); food import (adjimport); import weighted exchange rate (adjimport); Brent Blend oil price (adjlbrent).

NOTE: The diagonal shows histograms. The scatter diagrams show pairwise combinations of each variable. For example, the scatter plot in the second row shows the combination of NOK/USD exchange rate (vertical axis) and food import (horizontal axis).

Table 7: Rank test, oil price and import weighted exchange rate

| Rank | Eigenvalue | Trace test | p-value |
|---|---|---|---|
| 0 | 0,119 | 26,276 | 0,000 |
| 1 | 0,023 | 2,199 | 0,138 |

NOTE: Logarithms of detrended food import rate in tonnes and detrended import weighted exchange rate.

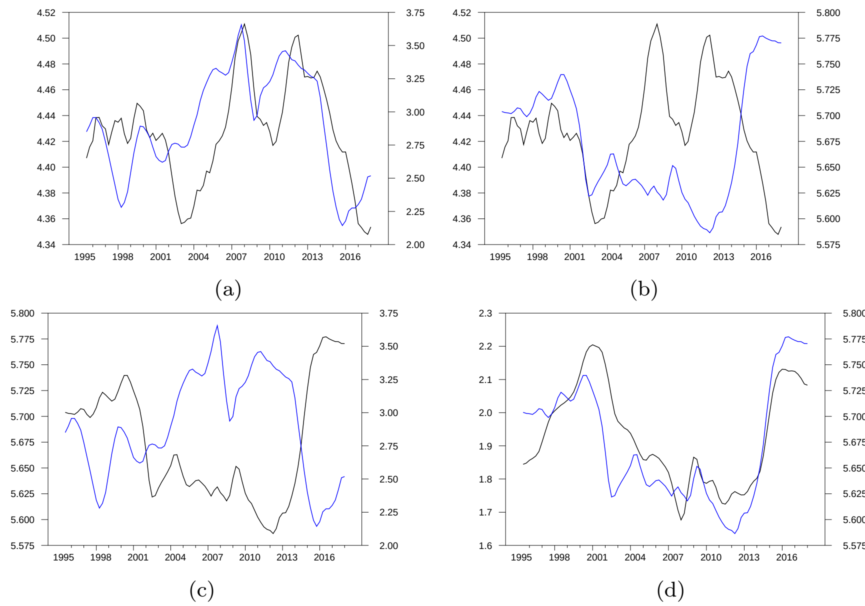



Figure 11: Panel (a): Food imports (black, left scale) vs. the price of Brent Blend oil. Panel (b): Food imports (black, left scale) vs. the import weighted exchange rate. Panel (c): Food imports (black, left scale) vs. the import weighted exchange rate. Panel (d): NOK/USD exchange rate (black, left scale) vs. the import weighted exchange rate.

NOTE: Detrended 4 quarter moving averages. Food imports is measured in logarithms of 1000 tonnes, the oil price in logarithms of USD, and the exchange rates in logarithms of NOK/foreign currency. The quarterly exchange rates are averages of monthly observations. Source: Statistics Norway (food imports), FRED (oil price), Norges Bank (exchange rates).

tion 5) however, the elasticity is as high as about $0,67$.

$$adjwxrate_t = \underset{(94{,}425)}{6,045} - \underset{(5{,}824)}{0,126} adjlbrent_t + u_{1t} \tag{4}$$

$$adjimport_t = \underset{(7{,}835)}{8,201} - \underset{(3.398)}{0.665} adjwxrate_t + u_{2t} \tag{5}$$

In the equation for changes in the import weighted exchange rate in Table 10, besides the seasonal dummy variable in quarter 3, the only significant coefficient is the adjustment coefficient, showing that about 30% of the disequilibrium is corrected in every period.

In the equation for changes in food imports ($\Delta adjimport$) in Table 11 we find a negative reaction (about $-0,38$) to its own lag, which constitutes an additional short-run correction impulse in addition to the expected ordinary equilibrium

Table 8: Rank test, food imports and import weighted exchange rate

| Rank | Eigenvalue | Trace test | p-value |
|---|---|---|---|
| 0 | 0,239 | 13,995 | 0,087 |
| 1 | 0,009 | 0,841 | 0,359 |

NOTE: Logarithms of detrended oil price detrended import weighted exchange rate.

Table 9: Variable exclusion test

| r | DGF | 5% C.V. | ADJWXRATE | ADJIMPORT | ADJBRENT | CONSTANT |
|---|---|---|---|---|---|---|
| 1 | 1 | 3,841 | 11,446 | 2,297 | 15,302 | 3,267 |
| | | | [0,001] | [0,130] | [0,000] | [0,071] |
| 2 | 2 | 5,991 | 21,507 | 15,576 | 27,955 | 15,853 |
| | | | [0,000] | [0,000] | [0,000] | [0,000] |

NOTE: ADJWXRATE, ADJIMPORT and ADJBRENT are detrended exchange rate, food imports and Brent Blend respectively.

Table 10: Equation 2: $\Delta adjwxrate_t$

| | Coefficient | Std. Error | $t$-ratio | p-value |
|---|---|---|---|---|
| EC1 | −0,2930 | 0,0868 | −3,700 | 0,000 |
| S3 | 0,0470 | 0,0109 | 4,3080 | 0,000 |

error adjustment to EC2 from Equation 5. Food imports react positively to EC1, implying that food imports increase when $u_{1t} > 0$ in Equation 4, i.e. when the exchange rate is above equilibrium. This is consistent with a positive relationship between imports and exchange rate depreciation.

Table 11: Equation 1: $\Delta adjimport_t$

| | Coefficient | Std. Error | $t$-ratio | p-value |
|---|---|---|---|---|
| $\Delta$adjimport$_{t-1}$ | −0,3780 | 0,0888 | −4,257 | 0,000 |
| EC1 | 0,4000 | 0,1197 | 3,146 | 0,002 |
| EC2 | −0,4430 | 0,1030 | −4,298 | 0,000 |
| S2 | 0,0910 | 0,1480 | 6,148 | 0,000 |

**The oil price - agricultural employment premise**

Disentangling labour migration between sectors is a complex issue. So far, there are no explicit register data available. One may still elicit useful information from time series data on employment and hours worked due to cointegration. If stationary linear combinations of nonstationary variables exist, the regressions are by definition not spurious, but describe *real* economic or social *equilibrium relations*. This does not mean, however, that the negative long-run relationship between hours worked in the petroleum and agricultural sectors is a result of migration from the agricultural to the petroleum sector only, or vice versa. It may also reflect migration to other sectors. In order to obtain more information about this possibility, inclusion of the construction sector has been tested.

The construction sector and the agricultural sector contain overlapping skills, rendering the former sector a likely recipient of labour from the agricultural sector. According to Figure 12 the correlation between hours worked in the agricultural and construction sectors is negative, which is consistent with a DD effect. The magnitude of the correlation coefficient is fairly low, however ($-0.11$), which indicates that the practical relevance is low. An *exclusion test* confirms that construction can be excluded from a system with the price of oil and hours worked in the agricultural and petroleum sectors, (see Table 12, where exclusion of the latter three variables (LPETRO: hours worked in the petroleum sector; LBRENT: the price of Brent Blend oil; TREND: a linear trend) is strongly rejected regardless of the rank of $\Pi$. Construction became insignificant when included in the VECM, consistent with the exclusion test. We therefore conclude that there is no significant long-run impact on the agricultural sector from the construction sector. Hence, a system with the remaining variables was estimated.

Table 12: Variable exclusion test

| r | DGF | 5% C.V. | LAGRI | LCONSTR | LPETRO | LBRENT | TREND |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 3.841 | 58.326 | 1.681 | 20.785 | 12.647 | 30.461 |
| | | | [0.000] | [0.195] | [0.000] | [0.000] | [0.000] |
| 2 | 2 | 5.991 | 60.714 | 1.904 | 22.313 | 15.093 | 30.622 |
| | | | [0.000] | [0.386] | [0.000] | [0.001] | [0.000] |

This model required 4 lags in the unrestricted VAR (hence 3 lags in the VECM) for residuals to become uncorrelated. *Pairwise* Johansen trace tests were conducted for the oil price vs hours worked in a) the oil sector, and b) the agricultural sector. In case b) the test marginally rejects a rank of zero (p-value about 0,14), but clearly cannot reject a rank of one (p-value about 0,81). In case a) the rank test clearly indicates one cointegrating relation. The time series graphs of the two cointegrating vectors indicate that both relations are mean reverting, suggesting that a model with two cointegrating vectors might be appropriate[10]. In order to identify the model, zero (i.e. exclusion) restrictions have been placed according to the rank tests. This implies that hours worked in the agricultural sector is excluded in the first relation, and hours worked in the oil sector in the second relation. Relation one thus consists of hours worked in the oil sector and the oil price, and the second relation of hours worked in the agricultural sector and the oil price.

[10] The lower graphs in panels a and b shows the cointegrating relations corrected for short term dynamics, i.e. lags of first differences.

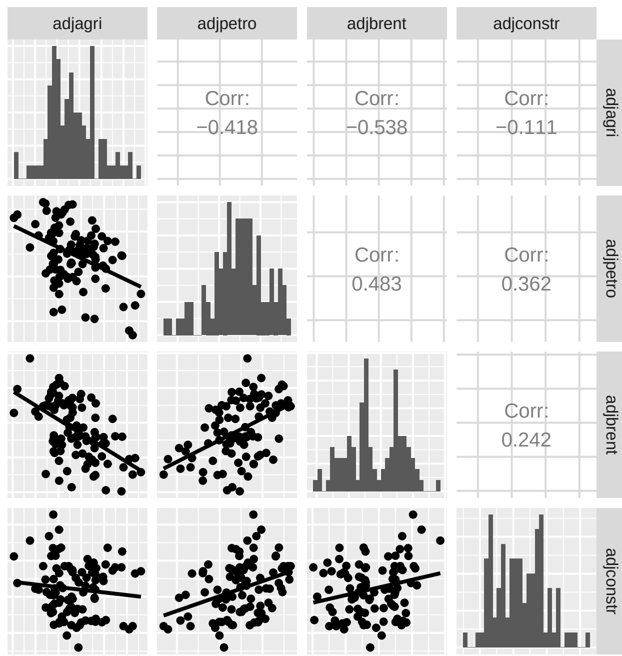



Figure 12: Detrended variables in logarithms, from left to right (top to bottom): hours worked in agricultural sector; hours worked in petroleum sector; oil price; hours worked in construction sector.

NOTE: The diagonal shows histograms. The scatter diagrams show pairwise combinations of each variable. For example, the scatter plot in the second row shows the combination of trend adjusted hours worked in the agricultural sector (vertical axis) and trend adjusted hours worked in the petroleum sector (horizontal axis).

Table 13: Rank test a) Oil price and hours worked in agriculture

| Rank | Eigenvalue | Trace | $p$-value |
|---|---|---|---|
| 0 | 0,202 | 22,134 | 0,137 |
| 1 | 0,018 | 1,655 | 0,974 |

Table 14: Rank test b) Oil price and hours worked in the oil sector

| Rank | Eigenvalue | Trace | $p$-value |
|---|---|---|---|
| 0 | 0,261 | 30,097 | 0,012 |
| 1 | 0,027 | 2,525 | 0,914 |

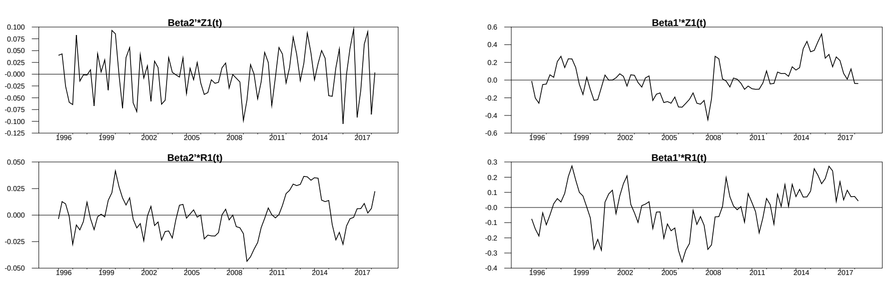
Hence we assume that there are equilibrium relations between the variables, as shown in Figure 13, where the agriculture equation, consistent with the rank test, displays some persistent deviations from the mean, but which nevertheless is mean reverting. Table 6 shows the long-run equations ($t$-statistics in parentheses).
[Table 14 about here]

$$lpetro_t = \underset{(8{,}212)}{0,493 lbrent} \underset{(-0{,}812)}{-0.001\, trend} + u_{1t}, \tag{6}$$

$$lagri_t = \underset{(-7{,}744)}{-0,116 lbrent} \underset{(-16{,}382)}{-0,006\, trend} + u_{2t} \tag{7}$$

where $u_t$ is the stationary equilibrium error. On average the long-run oil price elasticity of hours worked in agriculture is about $-0.12\%$. The oil price elasticity of the oil sector is about $0,5\%$.

Table 15 shows the short run dynamics of hours worked in the agricultural sector. About 30% of the disequilibrium is corrected each period. We also see additional error correction from own lagged changes. Finally there is a




(a) (b)

Figure 13: Cointegrating relations. Panel (a): The oil price – oil sector relation. Panel (b): The oil price – agricultural sector relation.

small negative effect on the mean change in the third quarter, measured by the seasonal dummy variable S3.

The changes in hours worked in the petroleum sector (Table 16) also adjust significantly to deviations from equilibrium in relation one, where about 58% of the deviation is corrected each period. In addition there is significant error correction to the second relation. We can analyse this adjustment in the following way: the lower the oil price keeping hours worked fixed, the more negative the equilibrium error becomes. The negative adjustment coefficient then contributes to a positive impulse to hours worked in the oil sector, which is consistent with the hypothesis that there is labour migration between the oil sector and the agricultural sector, and which is due to the oil price.

There is also a positive response to lagged changes in the agricultural sector, which at first sight appears counterintuitive. A tentative explanation is that an increase in hours worked in the agricultural sector creates higher demand for oil-dependent input factors, which in turn affects positively the demand for labour in the petroleum sector. This implies that the petroleum sector benefits from an expansion in the agricultural sector, but not vice versa. Finally there is error correction from own lagged changes, as in the agriculture equation.

Table 15: Equation 1: $\Delta lagri_t$

| | Coefficient | Std. Error | $t$-stat | p-value |
|---|---|---|---|---|
| const | 1.0951 | 0.7629 | 1.4350 | 0.1553 |
| $\Delta lagri_1$ | −0.5328 | 0.1644 | −3.2400 | 0.0018 |
| $\Delta lagri_2$ | −0.7380 | 0.1186 | −6.2200 | 0.0000 |
| $\Delta lagri_3$ | −0.6290 | 0.1027 | −6.1240 | 0.0000 |
| $\Delta lbrent_2$ | 0.0367 | 0.0191 | 1.9160 | 0.0591 |
| S3 | −0.0229 | 0.0142 | −1.6100 | 0.1116 |
| EC1 | −0.2766 | 0.1796 | −1.5400 | 0.1278 |

Table 16: Equation 2: $\Delta petro_t$

| | Coefficient | Std. Error | $t$-ratio | p-value |
|---|---|---|---|---|
| const | 2,5887 | 1,0244 | 2,5270 | 0,0136 |
| $\Delta agri\_1$ | 0,4622 | 0,2208 | 2,0930 | 0,0397 |
| $\Delta agri\_2$ | 0,2483 | 0,1593 | 1,5580 | 0,1234 |
| $\Delta petro\_1$ | −0,2062 | 0,1008 | −2,0460 | 0,0443 |
| $\Delta petro\_3$ | −0,1824 | 0,1043 | −1,7480 | 0,0845 |
| $\Delta lbrent\_3$ | −0,0568 | 0,0256 | −2,2160 | 0,0297 |
| S1 | −0,0549 | 0,0230 | −2,3900 | 0,0194 |
| S2 | −0,1168 | 0,0236 | −4,9410 | 0,0000 |
| S3 | −0,1103 | 0,0191 | −5,7660 | 0,0000 |
| EC1 | −0,5753 | 0,2413 | −2,3850 | 0,0196 |
| EC2 | −0,2042 | 0,0404 | −5,0600 | 0,0000 |

## 4.3 Summary of results

### 4.3.1 Classical Dutch Disease in the Norwegian economy

Statistics on hours worked in different sectors are consistent with presence of the Corden – Neary resource movement effect. Most notably business services, construction and property sales & administration have increased significantly, while agriculture and traditional industry have declined. Undoubtedly productivity gains are responsible for some part of the decline in agriculture, while the remaining part is likely to be due to Dutch Disease effects. This claim is substantiated theoretically by logical deduction, as well as by the econometric analysis of potential transmission channels.

### 4.3.2 Dutch Disease in the Norwegian agricultural sector

Three transmission channels have been identified and investigated: (1) the oil price — producer price channel; (2) The the oil price — exchange rate — food imports channel; (3) The Wage differential channel. Channels one and two have been investigated by vector equilibrium correction models. It is shown that there is a positive long-run equilibrium relationship between the oil price and producer prices, which is likely to affect prices of input factors positively, and hence profitability negatively. The negative effect may to some extent be neutralised if compensated by the annual Agricultural Agreement. To the best of my knowledge there is no specific statistics available to evaluate this question systematically. The second transmission channel is constituted by a (i) negative long-run equilibrium relationship between the oil price and the import-weighted exchange rate, and (ii) a negative long-run equilibrium relationship between the exchange rate and food imports. These relationships imply that the Norwegian krone appreciates when the oil price rises, and that food imports thus increase. Hence, by logical deduction, there is a positive long-run equilibrium relationship between the oil price and food imports, which is confirmed by graphical inspection and by correlation analysis.

A fourth relationship is the oil price vs hours worked in the agricultural and oil sectors. It is shown that there is a negative long-run equilibrium relationship between hours worked in the agricultural sector on one side and the oil price and hours worked in the oil sector on the other side. Hence there is a positive relationship between the oil price and hours worked in the oil sector.

All residual tests are conducted on the initial unrestricted vector autoregression model. In general the joint tests of normality are rejected. An exception is the equation for changes in hours worked in agriculture (a variable of primary interest). It is assumed that, by the central limit theorem, the test statistics are approximately normally distributed. Presence of heteroscedasticity (ARCH) and autocorrelation are generally rejected. Statistical inference is thus assumed to be valid. The models fit the data well, with $R^2$ ranging from $0,43$ in the equation for changes in the producer price (ignoring the exogenous oil price), to $0,81$ in the equation for changes in hours worked in the agricultural sector. In conclusion, all models are assumed to be statistically well specified and reliable.

# 5 Concluding remarks and suggestions for further research

Based on the theory of the Dutch Disease (DD) this paper has analysed the impact of the price of oil on the Norwegian agricultural sector, using Vector Equilibrium Correction models (VECM). A theoretical model is developed for the purpose. A causal chain using classical deductive reasoning is proposed, linking the oil price to food security via profitability. The premises in the causal chain are constituted by *stochastic time series variables*, which need to be stable long-run equilibrium relationships for the causal chain to be valid. The VEC models document that stable long-run equilibrium relations between the fundamental premises in the causal chain exist (research question 1), and with proper equilibrium adjustment in the endogenous variables (research question 2). In the VEC models, which generally fits the data well, the price of oil is identified as an exogenous driving force, and it has been shown that there is a direct negative effect on the work effort in agriculture from the petroleum sector, fully consistent with the hypothesised effects from the DD transmission channels. The absence of a statistical relationship between the construction and agricultural sectors further strengthens the DD hypothesis. It is therefore reasonable to assume that the classical resource movement effect results from a combination of the cost and imports channels (direct profitability effect) and the wage differential channel (relative effect), and that the overall effect is to make it less desirable to stay in the agricultural sector, as well as to discourage recruitment.

The effects of DD may be severe for society at large in the longer term. Essential to the farmland abandonment effect, the value of farmland for agricultural production depends on the price of agricultural products. As long as the farmer's share of the product price is low, alternative uses of farmland, such as residential plots, become more profitable. Farmers therefore become tempted to abandon their farmland and sell to for example residential builders. Fertile soil, however, is, for practical purposes, a non-renewable resource, just like oil. However, it is reasonable to believe that its destruction has far more severe consequences than does the depletion of oil reserves. Considering threats from population growth and climate change, it therefore becomes increasingly urgent not only to preserve the existing farmland, but also to cultivate more, in order to be on the safe side.

The protection of farmland can be enhanced by *strengthening the restrictions on reallocation*, but also by *increasing the incentives to cultivate*. As the DD hypothesis in this paper indicates, this can be accomplished by increasing agricultural profitability. Stronger restrictions on the importation of food and foodstuffs is likely to contribute in this respect. Higher profit margins will make small and marginal areas more profitable, which in turn contributes to less pressure on existing areas and livestock. The latter is important for *food quality* and hence human health, in that it reduces the need for antibiotics and other medication in meat and milk production, which has become a huge concern in modern industrial agriculture. As can be seen from Figure 14, Norwegian agriculture uses very little antibiotics. In addition to the health aspect, the high levels of antibiotics in foreign food production also creates unfair competition due to the volume enhancing effect of medication, analogous to the doping problem in sports.

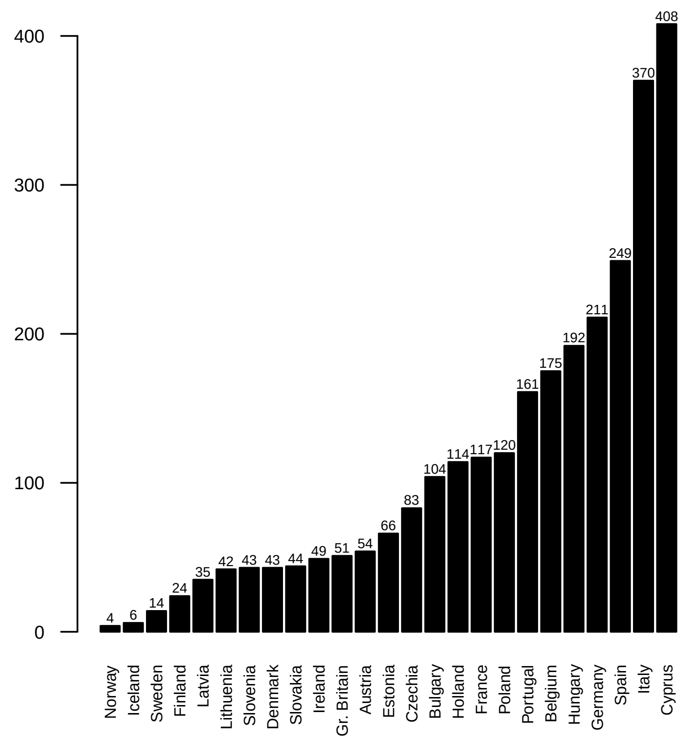



Figure 14: Annual sales of veterinary antimicrobial agents for food-producing species.
Note: measured in mg/population correction unit (PCU) for 30 European countries in 2011. The amounts in the different countries are normalised by the animal population at risk for being treated with antimicrobials in each country. Source: EMA (2018).

Finally, producing more of our food domestically will certainly reduce CO2 emissions from transportation, but also from production. The latter is due to the large differences in emission intensities around the world. According to Gerber et al. (2013)

> "Latin America and the Caribbean have the highest level of emissions (almost 1.3 gigatonnes CO2-eq), driven by an important production of specialized beef. Although at reduced pace in recent years, ongoing land-use change contributes to high CO2 emissions in the region, due to the expansion of both pasture and cropland for feed production."

Moreover, according to Gerber et al. (2013):

> "In North America, almost two-thirds of emissions originate from beef production which has high emission intensities. In contrast, beef in Western Europe mainly comes from dairy herds with much lower emission intensities."

Norway belongs to the latter group. It follows that stronger import restrictions on beef will benefit the environment, the profitability of farmers, and food security in Norway. These arguments are also valid for other countries. In other words, there are both local and global benefits from import restrictions. Many of the largest countries in the world are oil producers, and the DD – farmland abandonment – food security nexus is likely to be an issue with global impact. In this respect the present paper constitutes a pilot study.

In the initial phase of the Norwegian petroleum era a white paper from the Norwegian parliament was issued (Finansdepartementet (1974)), stating that the oil sector would generate job opportunities which might reduce employment in agriculture and fishing too much. Furthermore, it was ensured that counteracting public measures would be developed, so that the present settlement pattern could be maintained. Apparently, this intention has not been followed up properly. Based on the identified transmission channels, existing research and logical deduction, this paper claims that the export revenues from the North Sea oil bring far more severe challenges than the classical DD effect, which the white paper did not foresee. The root cause of these challenges, contained in the oil price – food security nexus, is that DD in the agricultural sector implies deterioration of food production resources. DD in the agricultural sector is therefore at odds with the principles of circular economics.

Among topical questions for further research are: (i) comparisons of the results in this article with other oil producing countries; (ii) a more thorough investigation of the impact of the various oil price – producer price channels on agricultural profitability; (iii) a study of the investment policy of the Norwegian pension (petroleum) fund, where societal infrastructure directed towards the protection of domestic farmland is included as a separate investment object.

# APPENDIX

## Residual tests in the oil price – producer price VECM

Table A1: Rao joint autocorrelation test

| Lag | Rao F | p-val |
|---|---|---|
| 1 | 0,204 | 0,936 |
| 2 | 1,205 | 0,297 |
| 3 | 1,487 | 0,130 |

Table A2: Univariate normality and ARCH tests

| Test | Test stat | p-val |
|---|---|---|
| ARCH(3) | 5,447 | 0,142 |
| Normality | 8,458 | 0,015 |

Table A3: $R^2$

| | |
|---|---|
| | $\Delta ppi_t$ |
| $R^2$ | 0.43 |
| | $\Delta brent_t$ |
| $R^2$ | 0.32 |

## Residual tests in the trend adjusted oil price – import weighted exchange rate – food imports VECM

Table A4: Rao joint autocorrelation test

| Lag | Rao F | p-val |
|---|---|---|
| 1 | 1,834 | 0,064 |
| 2 | 1,194 | 0,267 |
| 3 | 0,984 | 0,492 |

Table A5: Univariate normality and ARCH tests

| Variable/Test | Test stat | p-val |
|---|---|---|
| *Imports* | | |
| ARCH(3) | 2.457 | 0.293 |
| Normality | 2.580 | 0.275 |
| *Exch. rate* | | |
| ARCH(3) | 0.298 | 0.861 |
| Normality | 16.136 | 0,000 |

Table A6: $R^2$

| | |
|---|---|
| | $\Delta adjimport$ |
| $R^2$ | 0.72 |
| | $\Delta adjwxrate$ |
| $R^2$ | 0.65 |

### Residual tests in the oil price – agricultural and oil sector employment VECM

Table A7: Rao autocorrelation test

| Lag | Rao F | p-val |
|---|---|---|
| 1 | 1,166 | 0,319 |
| 2 | 1,034 | 0,423 |
| 3 | 1,012 | 0,454 |
| 4 | 1,100 | 0,332 |

Table A8: Univariate normality and ARCH tests

| Variable/Test | Test stat | p-val |
|---|---|---|
| *Agriculture* | | |
| ARCH(3) | 1.849 | 0,604 |
| Normality | 2.701 | 0,259 |
| *Oil sector* | | |
| ARCH(3) | 1.707 | 0,635 |
| Normality | 9,115 | 0,010 |

Table A9: $R^2$

| | |
|---|---|
| | $\Delta agri_t$ |
| $R^2$ | 0.81 |
| | $\Delta petro_t$ |
| $R^2$ | 0.76 |

## 6 Conflict of interest

The author declare that there are no conflicts of interest.

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