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Predicting the Macroeconomic Effects of Reducing Petroleum Activity in Norway: A Scenario Evaluation Approach

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1. Introduction

In the late nineteen sixties Norway discovered large oil and gas reserves on the continental shelf. This changed the economy profoundly and Norway quickly became a resource-exporting economy. Today, around fifty years after the discovery, the Norwegian petroleum sector employs roughly two hundred thousand workers and is the largest sector in terms of value creation, investment, and governmental and export revenues (Regjeringen, 2021). Moreover, its value chain reaches deep into the Norwegian economy. The offshore industry predictably relies on industrial equipment and on shipping services to sustain production, but services from lawyers, accountants, cleaners, and food caterers are also crucial to ensure well-functioning operations on the continental shelf. High demand for services from direct suppliers like these sets off a chain reaction, as these suppliers will in turn demand more from their own suppliers and thereby engender repercussions throughout the whole economy. Hernes et al. (2021) estimated that the Norwegian offshore industry and its value chain generated a value equivalent to six hundred billion NOK in 2019, which is the largest contribution to Gross Domestic Product (GDP) and accounts for as much as 17 percent. Besides the industry sector, they find strong ripple effects from the offshore industry within legal, engineering, financial, and transport services. In 2019, tax income from the extraction of fossil fuels comprised 20 percent of the Norwegian government's annual revenue, meaning shelf operations are a crucial component for ensuring the welfare for the Norwegian population (p. 12-13).

The offshore industry does, however, generate more than value. The utilization of gas turbines to generate heat, electricity, and mechanical power offshore makes the offshore industry the largest polluter in the Norwegian economy (Meld St. 13 2020-2021). Figure 1,1 shows how emissions from the petroleum sector have evolved since 1990 up until 2020. The emission level increased drastically early on, from eight million tons of CO_2 equivalents in 1990 to 14 million tons of CO_2 equivalents in 2000. Since then, the annual emission level has fluctuated between 13 and 15 million tons of CO_2 equivalents. In 2019, the level was at 13.2 million tons of CO_2 equivalents, making up 51 percent of quota regulated emissions and one fourth of

Norway’s total emissions (Meld St. 13 2020-2021).

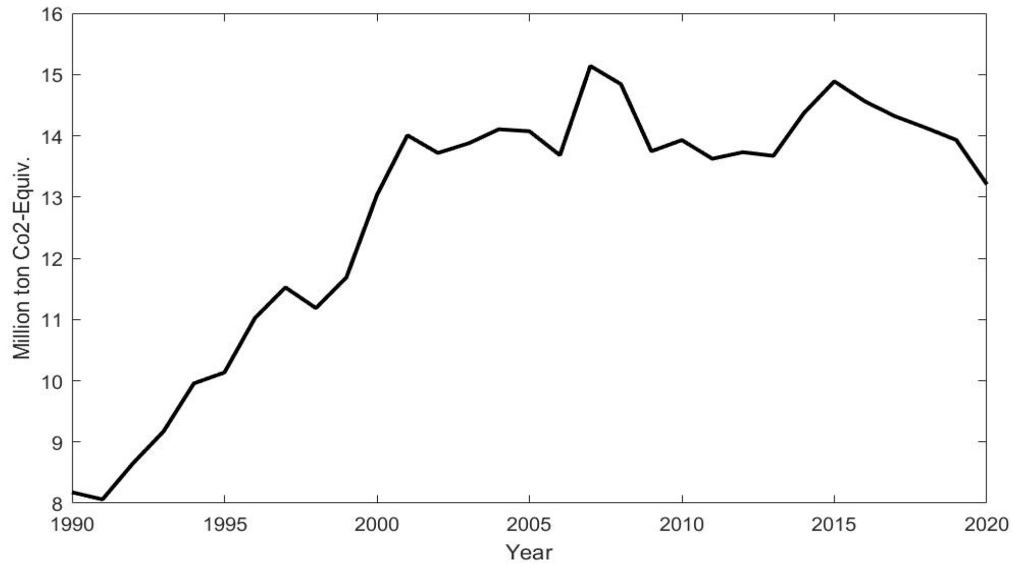

Figure 1, 1. *Air Pollution from Oil and Gas extraction (1990-2020). Source: Statistics Norway (2022a)*

At the same time, the amount of greenhouse gases in the atmosphere has started to accumulate and the global average temperature is being pushed upwards. Research indicates that the production and consumption of fossil fuels is the main contributor to climate change and emphasizes the need for an energy transformation. Consequently, Norway, along with the international community, has signed the Paris Agreement, in which 198 countries have committed to taking action to limit the global temperature increase to below 2℃ (United Nations, 2022a). Despite intensions being good, the development of satisfactory plans capable of achieving this goal has been absent. The latest report released from the Intergovernmental Panel on Climate Change (IPCC) shows that the average global temperature has already increased by 1.1℃, since pre-industrial times. Moreover, if the trend observed over the last three decades continues, average global temperature is expected to increase by 1.5℃ within twenty years (IPCC, 2022a). This prediction calls for immediate actions by policymakers, threatening the largest value creator of the Norwegian economy.

In our thesis, we seek to predict the macroeconomic effects of different policy options aimed at reducing Norway’s production of fossil fuels. Emission characteristics of the petroleum sector make the sector an obvious target for new climate policies. On the other hand, its central role in the domestic economy implies that reducing its activity will have severe implications for the Norwegian economy. This means that policymakers are facing a trade-off when implementing measures that reduces fossil fuel production. Politically, this has led to a heated debate, and arguments regarding whether Norway should keep supplying the world with fossil fuels are numerous. Importantly, research observes that arguments are to a large extent emotionally loaded, infused with notions of justice and the desire to do good. While these arguments may still be highly relevant, as students of economics, we find it crucial to highlight and quantify the trade-off between climate improvements and economic costs.

Following this discussion, we formulate our research question:

What are the macroeconomic effects of measures aimed at reducing production of fossil fuels in Norway?

We investigate this question by estimating a Bayesian multivariate autoregressive (BVAR) model and utilize it by conducting conditional forecasts. The conditions are imposed directly on production of fossil fuels and the price of oil, and they are based both on policy objectives set by the Norwegian state as well as up-to-date research published by IPCC. We investigate three scenarios in our empirical analysis, all of which start in 2020 and end in 2030. The year 2030 is an important reference year for most climate policies, as important objectives are set to be reached by this year (Konkraft, 2020). Our main interest is in imposing conditions on production and price, and investigating the resulting predictions for GDP, the Consumer price index (CPI), employment, the real effective exchange rate (REER), and labor productivity. Finally, after investigating main macroeconomic variables under three scenarios, we extend one of our three scenarios by conducting a sectoral analysis. This analysis considers five sectors of the Norwegian economy and investigate predictions for sector-specific production, investment, employment, wage, and labor productivity.

There have been several papers investigating the economic effects of resource extraction. A much-discussed concept within this literature is the Dutch disease. This concept, stemming from the natural gas discoveries made by the Netherlands in the nineteen sixties, refers to the adverse effects experienced by other sectors of the economy following the discovery (Corden, 1984). Later, Sachs and Warner (2001) furthermore showed that resource exploration often reverses economic growth, rendering the discovery of fossil fuels a curse rather than a blessing. Following the implications from these papers, one would expect that, following a reduction in the extraction of fossil fuels, other sectors in the Norwegian economy would prosper and that the Norwegian economy would continue to grow. However, our analysis suggests otherwise.

Much work has been done within the fields of Dutch disease in Norway. Bjørnland and Thorsrud (2016) emphasizes the importance of allowing for "learning by doing" (LBD) both within sectors and for spillovers across sectors. The authors find that, in the aftermath of an activity shock in the Norwegian petroleum sector, there are sizable positive effects on the overall productivity level in the economy and on GDP. Furthermore, a positive oil price shock was found to have a negative effect on a large share of the economy. These findings are in line with our results, namely that GDP and productivity levels contract substantially in response to a reduction in fossil fuel production. We also observe that increasing oil price tends to decrease employment and have a negative impact on the productivity level.

Comparing our results to those in the Dutch disease literature does, however, lead to some surprises. In our analysis, the REER is insensitive to fossil fuel production and is decreasing in the price of oil. Hence, our predictions imply that there are factors other than production and the price of fossil fuels that determine the long-term REER. These results will be discussed further in later sections. We do, however, find it important to stress that most Dutch disease studies consider short-to-medium term effects, i.e., 1-5 years, whereas we consider a horizon of 10 years. As such, the results may differ simply due to different timelines. In order to predict 10 years ahead, we have chosen to utilize annual data in our main analysis. The strength of this is that we are able to capture long-term trends and avoid unnecessary noise, when investigating the relationship between a number of endogenous variables. However, it is important to bear in mind the reduced form characteristics of forecasting, which we will discuss later. The absence of structural identification is a potential explanation for the disparities we observe from previous Dutch disease studies conducted on the Norwegian economy.

To the best of our knowledge, the only paper that investigate the macroeconomic effects of reducing activity in the fossil fuel sector is Aune et al. (2020). There are several differences between the assumptions used in our analysis and in theirs, however, such that our results differ considerably from theirs in many aspects. For one, the model used in their paper considers policies with a deadline of 2050, as opposed to the sector-specific objective set by the Norwegian state for 2030. Hence, they analyze the macroeconomic effects stemming from policy measures aimed simply at reducing fossil fuel production, while we analyze the macroeconomic effects stemming from the implementation of that which is required to achieve the goals set out in the Paris Agreement. Furthermore, our analysis extends Aune et al. (2020) by investigating how the price of oil can affect the path to 2030. The authors conclude that the macroeconomic effects of reductions in fossil fuel sector activity are in general small. In contrast, we demonstrate that reducing production to a level consistent with climate objectives for 2030 has serious effects on macroeconomic variables and, as such, our findings differ substantially from the predictions in Aune et al. (2020). Among other things, we predict average annual GDP growth in the time interval 2023-2030 to be one percentage point lower than that predicted in their study. Moreover, we predict an extended period of negative inflation and reduced productivity among Norwegian workers, whereas they predict these variables to grow on the path towards 2030. Possible explanations and implications of this will be discussed thoroughly down below. Given the wide range of assumptions that can be used in the analysis of the macroeconomic effects of a reduction in fossil fuel production, we believe our research can contribute to a nuanced picture of how the economy will transform towards 2030, as the importance of achieving emission reduction goals are ever increasing.

The remainder of this paper is structured as follows. First, we take a deep dive in the existing literature on familiar topics. Following this, we introduce conditional forecasting in a Bayesian framework and provide a data description. We then carry out our empirical analysis and discuss the result in light of the existing literature. Finally, we summarize our findings and conclude.

2. Literature review

We believe that in order to fully understand how a resource-dependent economy is going to be affected by reducing resource extraction, we will need a solid theoretical framework. Hence, in this section we are trying to get a better understanding of how the energy transition is going to affect the Norwegian economy based on theoretical frameworks and, in addition, review recent research conducted within the fields. The challenge of investigating such a transformation, is that the concept of reducing production of fossil fuels is rather new, and that theoretical frameworks within the field are underdeveloped. However, theoretical frameworks that cast light upon the effects of becoming a resource-dependent economy can be dated all the way back to the early 70's and is still developing as of today. Even though we are analyzing the opposite, transmission channels highlighted by these frameworks are going to be crucial to understand, before investigating our own results. Moreover, the effects identified in these models, in the opposite direction, will serve as benchmark for our empirical analysis in later sections.

Corden and Neary (1982) puts forward a theoretical model in which they investigate the medium-run effect of asymmetric growth in a small open economy. They consider an economy that produces two goods which are traded at given world prices, and a third non-traded good, where price moves such that domestic supply equals domestic demand. One of the traded goods can be thought of as energy and the other as a manufactured good, while the non-traded good can be thought of as services. They proceed by assuming balanced trade and ignore any monetary considerations, which means that only relative prices are being determined. The real exchange rate in the model is being defined as the relative price of the non-tradeable to tradeable goods. Real wages are perfectly flexible and ensures that the whole labor force is being employed at all times. At last, each sector uses labor and capital as factor inputs. Labor is assumed to be perfectly mobile, while capital is assumed to be sector specific.

They use this framework to, among other things, investigate the effects of a resource boom in the energy sector. They identify two effects which they refer to as the *resource movement effect* and the *spending effect*. The first effect arises from increased labor demand in the energy sector, while keeping the real exchange rate fixed. Due to higher marginal products in the energy sector, labor will reallocate from both the manufacturing and service sector towards the energy sector. For a given real exchange rate, the resource movement effect leads to excess demand for services. Hence, in order to restore equilibrium, there must be a real appreciation. This appreciation will switch demand away from the service sector, but also act as a dampening effect on the fall in output induced by the resource movement effect. The spending effect arises from increased demand for services under a constant real exchange rate, which is due to increased income in the overall economy, followed by the resource boom. Excess demand for services requires that the real exchange rate appreciates. This will once more attract employment towards the service sector. We see that the two effects combined will contribute to a real appreciation. However, the outcome in the service sector is ambiguous. Both effects tend to increase the price of services, but output produced is only increasing due to the spending effect. The resource movement effect, on the other hand, seems to depress output in the service sector. The new equilibrium will therefore depend on the relative strength of these effect. The outcome in the manufacturing sector is less ambiguous. First, the resource movement effect draws workers out from the manufacturing sector towards the energy sector. Second, the real appreciation caused by both effects, increases the wage level in the overall economy and induces workers to reallocate toward the service sector, and reduces employment in manufacturing further. Hence, the manufacturing sector is unambiguously negatively affected by the resource boom.

The model presented above is the traditional and most basic framework used when investigating impacts of asymmetric growth in an economy. The evident inverse relationship between natural resource exploration and the development in the manufacturing sector depends heavily on the assumptions that is being imposed. This has motivated several extensions of the model. Bjørnland and Thorsrud (2016) puts forward an alternative model where they implement productivity as an endogenous variable and allows for productivity spillovers across sectors, and learning by doing (LBD) effects within sectors. Importantly, due to LBD and spillover effects, one unit of labor employed in the tradeable sector contributes to productivity growth in the tradeable sector, but a fraction of it will spill over to the non-tradeable sector and vice versa. At last, they allow for direct LBD spillover effects from the energy sector to both tradeable, as well as non-tradeable sector. Besides from introducing productivity as an endogenous variable and using labor as the only production factor, the model can be thought of as identical to the one introduced by Corden and Neary above.

Followed by a boom in the energy sector, they identify the traditional Dutch disease effect, where the amount of labor in the non-traded sector has increased. However, since productivity is endogenous in the model, the relative productivity level across sectors also changes. Hence, the resource movement causes the productivity gap between the traded and non-traded sector to diminish. In the new equilibrium, production has shifted towards the non-tradeable sector, however, this is due to a shift in the equilibrium relative productivity between the sectors, rather than factor allocations as is conventional. Furthermore, since the labor share between sectors remains constant, the real exchange rate is required to depreciate in order to make domestic supply equal to domestic demand. This is contrary to the results identified in the traditional model. Under sufficiently strong LBD and spillover effects, they also find that production in both tradeable and non-tradable sector increases followed by the resource boom.

To test the theoretical predictions, they specify a dynamic factor model (DFM), This framework allows them to estimate the direct and indirect spillovers between several sectors in the Norwegian economy. Followed by a resource boom, they find substantial productivity spillovers from the resource sector to the domestic economy. More specifically, mainland GDP increases for a prolonged period of time. After one to two years, the variance decomposition predicts that 25-30 percent of the variance in mainland GDP is explained by the resource shock, and as much as 50 percent of the variation in the overall productivity level. Investment in the domestic economy experiences a boom followed by the shock and wages increases with a lag. The effect on employment and real exchange rate is, however, small and mostly insignificant. Producer prices, consumer prices and terms of trade are to a large extent unaffected by the resource activity shock.

Bjørnland and Thorsrud investigate further how a commodity-specific price shock affects the domestic economy. This type of shock can be thought of as an increase in the price that is being caused by market specific factors and is not driven by global demand. Compared to the resource shock, where the whole economy experienced growth, the effects followed by this shock is mostly negligible for mainland GDP and productivity. However, the shock is able to explain 60 percent of the variation in the real exchange rate, which experiences a strong appreciation. Investment, producer prices, consumer prices, and terms of trade tends to increase, and the oil price shock is able to explain a substantial amount of the variation in these variables, compared to the resource activity shock.

Bjørnland et al. (2019) extends the theoretical framework developed in Bjørnland and Thorsrud (2016) further and highlight the lack of productivity dynamics stemming from resource movement effects in existing models. In addition to having tradeable and non-tradeable sector in their model, they augment it with an oil-service sector which serve as input for oil extraction. They use this model to investigate the effects of both an oil price and an oil activity shock. Followed by increased oil price, income increases and demand for non-tradeable goods are being pushed up. The price of non-traded goods needs to increase to ensure market balance. Hence, the oil price shock generates the traditional Dutch disease symptoms. Employment in the non-traded sector has increased at the expense of tradeable sector, and a real appreciation occurs. Central in their paper is the question of how the income and productivity level in the economy is being affected. The increased oil price seems to have unclear effects on these variables. Depending on the size of the LBD and spillover effect, the aggregate productivity and income level might be negatively affected followed by the oil price shock. The oil activity shock generates similar equilibrium characteristics. The real appreciation hurts the tradeable sector which causes employment to decline. Employment in the oil service sector increases unambiguously, while the effects on employment in the non-traded sector will depend on the relative strength of the spending effect and the resource movement effect. The spending effect increases it, while the resource movement effect tends to lower it. The oil activity shock does however have opposite results, compared to the oil price shock, regarding aggregate income and productivity level. They show that if LBD effects within the oil service sector are sufficiently strong, and strong spillover effects are received by other sectors, the oil activity shock can act as an engine of growth. This is contrary to the results found in traditional Dutch disease models and might be an important driver for why Norway has experienced solid growth rates in the overall economy.

They test the predictions of their theoretical model by specifying a time-varying VAR. This model is being used to identify an oil price and an oil activity shock. The shocks are then being regressed on productivity developments in various sectors in the Norwegian economy. As predicted by their theoretical mode, they do not find productivity spillovers to the Norwegian sectors followed by the oil price shock. Moreover, their results shows that a large share of the industries are either unaffected or negatively affected by this shock. The oil activity shock, on the other hand, seems to increase the productivity level across all sectors. Most strikingly, the tradeable sector experiences the largest effects, which is contrary to predictions made by traditional Dutch disease models. Their methodology also allows them to check whether LBD effects creates higher productivity growth over time. Their findings suggests that there is knowledge accumulation over time, and that an oil activity shock lifts the productivity level in the overall economy.

The literature review so far has shown us that resource movement and spending effects predicted by theoretical models are to a varying degree affecting the Norwegian economy. Based on the findings in the paper recently reviewed, it might seem like we can expect a negative impact on the domestic economy, especially with regards to productivity, followed by reduced activity in the fossil fuels sector. It is also reasonable to believe that the spending and resource movement effect can cause movements in the labor force, and combined with labor market frictions, affect the employment share in the overall economy. An important factor in this transition is the competitiveness of the Norwegian economy, i.e., the REER. Empirical evidence from above suggests small effects in the real exchange rate followed by activity shocks, while price shocks tend to have larger effects and causes it to appreciate.

Aune et al. (2020) investigate the long-term macroeconomic effects of reducing fossil fuel production towards 2050. They conduct a scenario-evaluation analysis, in which they investigate two scenarios. In the first scenario, they implement a moderate policy option. This involves permitting firms to extract and search for remaining oil and gas reserves, as long as licenses for the geographical area have been assigned before

January 1st, 2022. From then and onwards, license assignment stops completely. The second scenario extends the first by introducing a number of changes in taxes and financial conditions for fossil fuel producing firms. Compared to the first scenario, this will reduce incentives for fossil fuel production among firms operating in already existing areas. The authors assume that the stimulus package released under the pandemic applies until 2024, see Aune et al. (2020, p. 50) for details, and therefore that political measures first take full effect in 2025. Both scenarios are being compared to a baseline scenario, in which they assume that current Norwegian fossil fuel policy is being extended towards 2050. Importantly, the baseline scenario is characterized by a substantial decline in petroleum production as well. More specifically, they assume that the gross product from oil and gas as a share of mainland GDP is being reduced from constituting 15 percent in 2023, to three percent in 2050. A detailed comparison between our results and their findings from their second scenario is provided in section 5.4, but their conclusion is that the macroeconomic effects are in general small, even in their strictest scenario. They point at three attributes that dampens the effects of reducing activity in the fossil fuel sector. First, the baseline scenario is also influenced by a substantial reduction in activity, which means that policies taking effect in 2030 generates less impact by nature. Second, the policy rate is being lowered by the central bank. This causes a depreciation of the Norwegian krone (NOK), which fosters better competition terms and efficient reallocation of labor and capital. Third, the pension fund global is not affected by the policy implementation and increases its value when the NOK is depreciating. This, combined with automatic stabilizers and fiscal policy, dampens the effects on the Norwegian economy.

In our analysis, we do not make assumptions with regards to what type of policy that is being implemented and to what extent these political measures alter the incentives of fossil fuel producers. We impose conditions, which are based on sector-specific emission reduction goals specified towards 2030, directly on production. This prevents us from making poor assumptions with regards to for example, the development of the quota price, which depends on far more factors than Norwegian fossil fuel extraction. Furthermore, none of the policy options suggested above implements the goal of reducing emissions by 40 percent already by 2030. Even though they measure activity in terms of gross product, and we in terms of production volume, they are assuming that fossil fuel prices remain constant throughout their analysis. This makes our production volume and their gross product reasonably comparable. In according to our emission data on fossil fuel production, the cut they impose in the first scenario barely makes up 20 percent of the cut required to achieve the sector-specific emission reduction by 2030. Despite slightly better performance by the second scenario, which obtains approximately 30 percent of what is required, it is still far away from achieving the target. Furthermore, our analysis differs from theirs by not taking into account the effects of monetary and fiscal policy. Their analysis showed that these factors are important for how the Norwegian economy adjusts to the policy changes. Therefore, implications of this are being discussed more in detail in section 5.4. At last, our analysis extends theirs by allowing for different responses in the oil price. As theory would have it, and as we show in later sections, the development in the oil price has important implications for how the Norwegian economy transforms towards 2030.

3. Methodology

This section will outline the statistical framework applied in the rest of this thesis.

3.1 Conditional Forecasting

Our empirical methodology builds upon the VAR framework. As briefly mentioned in the introduction, using this framework for forecasting allows us to capture interactions between several endogenous variables, which has been shown to increase forecast accuracy relative to univariate equations (Doan et al., 2007). We will impose conditions on oil production and price, based on policy objectives and emission data, thereafter, we exploit the interactions and estimate how this will affect the path of remaining variables. Hence, our framework allows us to investigate the path of the Norwegian economy under a minimum number of assumptions, preventing us from imposing restrictions on interactions, as well as the future of other macroeconomic variables. In order to get a better understanding of our methodology, we derive the VAR model and illustrate how conditions imposed affects the system. Technical derivations are based on Dieppe et al. (2018), unless otherwise is specified. Consider a general VAR model with n endogenous variables, p lags, and m exogenous variables. The model in its structural form can be specified as:

$$D_0 y_t = D_1 y_{t-1} + D_2 y_{t-2} + \cdots + D_p y_{t-p} + F x_t + \eta_t \tag{1,1}$$

Where y_t is a $n \times 1$ vector of endogenous data, $D_0, D_1 \dots, D_p$ are matrices of dimension $n \times n$, F is a $n \times m$ matrix, and x_t is a vector of dimension $m \times 1$, consisting of exogenous regressors such as, constant terms or time trends. Finally, $\eta_t \sim \mathcal{N}(0, \Gamma)$ is a vector of structural shocks with variance-covariance matrix Γ.

When model (1,1) is used for forecasting, we need to transform it to reduced form:

$$y_t = A_1 y_{t-1} + A_2 y_{t-2} + \cdots + A_p y_{t-p} + C x_t + \varepsilon_t \tag{1,2}$$

With $\varepsilon_t \sim \mathcal{N}(0, \Sigma)$ as a vector consisting of reduced form residuals with Σ as the covariance-variance matrix. We define:

$$D = D_0^{-1}$$

The following relationship between the structural parameters and the reduced-form parameters apply:

$$A_i = D D_i \tag{1,3}$$

$$C = DF \tag{1,4}$$

$$\varepsilon_t = D \eta_t \tag{1,5}$$

Using model (1,2) for forecasting, we may obtain the following expression, using recursive iteration, for the forecast $T + h$ periods ahead:

$$y_{T+h} = \sum_{j=1}^{p} A_j^{(h)} y_{T-j+1} + \sum_{j=1}^{h} C_j^{(h)} x_{T+j} + \sum_{j=1}^{p} B_j^{(h)} \varepsilon_{T+j} \tag{1,6}$$

From the right-hand side (RHS) of (1,6), one can see that the forecast consists of three parts. The first term represents the endogenous variables of the model. The second includes the exogenous variables of the model, while the third involves future values of reduced form residuals. $A_j^{(h)}, C_j^{(h)}, B_j^{(h)}$ are the respective coefficient matrices. $B_j^{(h)}$ provides the responses of y_{T+h} to shocks in $y_{T+1}, y_{T+2}, \dots, y_{T+h}$ and is therefore a series of impulse response function matrices. These matrices are of particular interest to us as it is fundamental to our methodology. To make things clearer we denote:

$$B_j^{(h)} = \Psi_{h-j}$$

Where Ψ_i represents the impulse response functions of the reduced form VAR. Hence, we may rewrite (1,6) as:

$$y_{T+h} = \sum_{j=1}^{p} A_j^{(h)} y_{T-j+1} + \sum_{j=1}^{h} C_j^{h} x_{T+j} + \sum_{j=1}^{h} \Psi_{h-j} \varepsilon_{T+j}$$

By using the relationship stated in (1,5), combined with the following relationship between structural shocks and reduced form residuals:

$$\Psi_{h-j} \varepsilon_{T+j} = \Psi_{h-j} D D^{-1} \varepsilon_{T+j} = \widetilde{\Psi}_{h-j} \eta_{T+j}$$

We may express our forecast as:

$$y_{T+h} = \sum_{j=1}^{p} A_j^{(h)} y_{T-j+1} + \sum_{j=1}^{h} C_j^{(h)} x_{T+j} + \sum_{j=1}^{h} \widetilde{\Psi}_{h-j} \eta_{T+j} \tag{1,7}$$

The two first terms on the RHS of (1,7) constitute the unconditional forecast of y_{T+h}. We define:

$$\sum_{j=1}^{p} A_j^{(h)} y_{T-j+1} + \sum_{j=1}^{h} C_j^{(h)} x_{T+j} = \tilde{y}_{T+h}$$

Our methodology consists of imposing conditions on certain variables. The derivations above enable us to visualize how these conditions will affect the VAR system. For instance, assume that we impose a condition on variable i in period $T + h$ which states that:

$$y_{i,T+h} = \bar{y}$$

By considering row i in (1,7), we obtain:

$$y_{i,T+h} = \tilde{y}_{i,T+h} + \sum_{j=1}^{h} \widetilde{\Psi}_{h-j,i} \eta_{T+j} = \bar{y}$$

Rearrange and we get:

$$\sum_{j=1}^{h} \widetilde{\Psi}_{h-j,i} \eta_{T+j} = \bar{y} - \tilde{y}_{i,T+h}$$

From the last expression it is evident that what we essentially do when imposing conditions on a variable is to restrict future structural shocks. The procedure forward is to draw these structural disturbances, such that the constraints imposed are being satisfied. This is done through a Gibbs sampling algorithm. In our analysis we allow the conditions to be generated by all the structural shocks in the model. This might potentially generate some undesirable results, which we will discuss more in detail in section 6.4. In our scenario analysis we specify the VAR model such that $n = 7$ and $p = 2$, while we include two additional lags in the sectoral analysis, that is $p = 4$, due to higher frequency data. A constant is included in both cases.

3.2 Bayesian Estimation

The Bayesian approach to statistics is becoming increasingly popular in the macroeconomic literature. When doing macroeconomic analysis using VAR models, one is typically estimating a large number of parameters. This is particularly challenging when using macroeconomic data since sample sizes often are small. As described below, the Bayesian estimation methodology provides us a formal way of shrinking parameters and has been found to improve forecast performance (Koop, 2011). Moreover, unlike the classical approach, Bayesian estimation does not rely on asymptotic theory. When using small samples, classical estimation might result in nonconvergence, and therefore provide inaccurate estimates (Asparouhov & Muthèn, 2012). These issues can be avoided by applying the Bayesian estimation methodology and will therefore be applied in our estimation. In the remainder of this section, we describe the basic ideas behind Bayesian statistics and how these are applied in our thesis.

Assume that y is a vector or matrix of data, and θ to be a vector or matrix consisting of the parameters of the model which seeks to explain y. Our interest lies in θ and we want to learn about it given our data. In Bayesian statistics we obtain this knowledge through the following rule:

$$p(\theta|y) = \frac{p(y|\theta)p(\theta)}{p(y)}$$

We can remove the denominator as this is nothing else than a normalizing variable, and obtain:

$$p(\theta|y) \propto p(y|\theta)p(\theta)$$

The left-hand side (LHS) is being referred to as the posterior distribution, while the RHS consist of two terms referred to as the likelihood function and the prior distribution, respectively. The equation states that the posterior distribution is proportional to the product of the likelihood function and the prior distribution. The prior does not depend upon the data and reflects knowledge regarding the parameters of interest before seeing the data, while the likelihood function describes the distribution of the data conditional on the parameters. Together, they form the posterior distribution, in which allows us to carry inference about the parameter values, compute point estimates, and so forth (Koop, 2003).

Note that the prior specified for the parameters of interest, is simply denoted as $p(\theta)$. However, the prior distribution itself will also depend on a set of parameters, known as hyperparameters. In our case, these are known and specified by us. We have adopted the Minnesota prior proposed by Litterman (1986). Following his strategy, the VAR residual variance-covariance matrix is assumed to be known, so the piece left to estimate is the parameters. In order to do so, we need the likelihood function and a prior for the parameters. As stated above, the residuals of the VAR model follow a multivariate normal distribution with mean 0 and covariance-variance matrix Σ, which implies that y also follows a multivariate normal distribution. For the prior distribution it is assumed that θ follows a multivariate normal distribution with mean θ_0 and variance-covariance matrix Ω_0:

$$p(\theta) \sim \mathcal{N}(\theta_0, \Omega_0)$$

Following Litterman's strategy, we assume that each of our variables contain a unit root in their first lag, and that coefficients for further lags and cross-variable lags are equal to zero. Furthermore, it is assumed that no covariance exists across terms in θ, so Ω_0 is diagonal. For the variances, Litterman argued that the further the lag, the more confident we can be that it is zero. The same logic applies to coefficients relating variables to other variables. Hence, our prior beliefs about the variances of these types of coefficients should be small.

The parameter values are chosen by the researcher. This choice is typically founded in economic theory, empirical research, or simulation procedures. Since our task is to make predictions about the Norwegian economy 10 years ahead, followed by imposing strict political measures that have never found place, there will be a substantial amount of uncertainty regarding our coefficients. Moreover, available literature within these fields is limited, making guesses about the parameters particularly challenging. Hence, we have chosen to follow what we typically find in the traditional macroeconomic literature. Our hyperparameters regarding the variance-covariance matrix are therefore specified as follows:

$$\lambda_1 = 0.1$$

$$\lambda_2 = 0{,}5$$

$$\lambda_3 = 1$$

Where λ_1 is the overall tightness parameter, λ_2 the cross-variable specific parameter, and λ_3 a scaling parameter that controls the speed at which coefficients at further lags than one converges towards zero. Once hyperparameters and data sample are chosen, we can proceed by combining the prior distribution and the likelihood function. The remainder of this section is based on Dieppe et al. (2016).

In our case, there will be several parameters of interest, meaning that the previously mentioned posterior distribution become a joint distribution. Our interest, is however, in the marginal distribution of a particular element. To get this, we need to extract the marginal distribution of a particular element from the joint distribution. Assume for instance that there are two parameters, θ_1 and θ_2, and that we are interested in the marginal distribution of θ_1. To get this, we integrate out the remainder of the parameters:

$$p(\theta_1|y) = \int p(\theta_1, \theta_2|y)d\theta_2$$

It is from this distribution that we draw inference about θ_1 and vice versa for θ_2. Once the marginal distribution of a particular element is obtained, we can compute a point estimate and its attached credibility interval. Our point estimator is the median, which is computed by minimizing an absolute value loss function. The credibility interval is given as:

$$p(\theta_L \leq \theta \geq \theta_U) = \alpha$$

Which implies that θ will lie within the upper and lower limit with a probability of α, in our case $\alpha = 0{,}68$. The interval is derived by trimming both tails of the marginal posterior distribution.

These ideas are directly transferable to forecasting, but rather than seeking out the posterior distribution of a particular parameter, we seek the posterior predictive distribution. We can denote it as:

$$f(y_{T+1:T+h}|y_T)$$

In words, the distribution of future datapoints $y_{T+1}, y_{T+2}, \dots, y_{T+h}$, conditional on the information set y_T. Assume that θ is yet again the parameters of interest. Then, we can obtain the predictive posterior distribution as:

$$f(y_{T+1:T+h}|y_T) = \int_\theta f(y_{T+1:T+h}, \theta | y_T) d\theta$$

$$= \int_\theta \frac{f(y_{T+1:T+h}, \theta, y_T)}{f(y_T)} d\theta$$

$$= \int_\theta \frac{f(y_{T+1:T+h}, \theta, y_T)}{f(y_T, \theta)} \frac{f(y_T, \theta)}{f(y_T)} d\theta$$

$$= \int_\theta f(y_{T+1:T+h}|\theta, y_T) f(\theta|y_T) d\theta$$

Which shows that the predictive posterior distribution rewrites as an integrated product of the posterior distribution and the predictive distribution of future observations, conditional on data and parameters. From here it is straight forward to estimate the median forecast and obtain the credibility interval, as illustrated above.

4. Data

4.1 Yearly Data

Our main model is constructed with the purpose of predicting the main macroeconomic variables. Yearly observations for GDP, CPI, Employment, and labor productivity are gathered from Statistics Norway. GDP is measured as the market value of the gross product and in terms of million NOK and fixed 2015 prices (Statistics Norway, 2022b). The CPI is computed as the yearly price level, using 2015 as the basis year (Statistics Norway, 2022c). Employment is the share of the population between age 15-74, that is currently accounted as employed (Statistics Norway, 2022d) Labor productivity is computed as GDP, measured as explained above, over total hours worked and measured in terms of NOK (Statistics Norway, 2022e)

Naturally, we also include the REER, which is a core variable in the Dutch disease literature. This variable is gathered from the Bank for International Settlements (BIS) and is denoted in terms of dollars (BIS, 2022). The Oil and gas production is collected from the Norwegian Oil directorate and is measured in terms of millions of cubic meters of oil equivalents (Norsk Petroleum, 2022a). To fix ideas, one oil equivalent cubic meter makes up approximately 6,3 barrels of oil (Norwegian Petroleum Directorate, 2020). As Norway is a small open economy that produce fossil fuels, we believe that the response of remaining producers will have an impact on how Norway performs under the transformation. Hence, we have included the oil price, which enables us to model different responses in the oil price, based on how production develops globally, followed by Norway's cut. Ultimately, we would prefer to have the price of gas as well. However, we were not able to obtain this for the chosen sample period. The oil price is collected from the US Energy Information Administration (EIA) and has been converted from price per barrel to price per one cubic meter of oil equivalent (EIA, 2022), using transfer rates from the Norwegian Petroleum Directorate.

The outbreak of Covid 19 in 2020 caused severe effects in many economies around the world. Our concern is that many of our variables shows signs of the pandemic and that this could have had an impact in our forecasts. We are considering this as a one-time event and for that reason exclude 2020 from our dataset. In appendix B, we include 2020 in our sample and find that the effects from covid does not seem to have a substantial impact on the forecast of our yearly variables. We do, however, believe that the effects are bigger on variables following a quarterly frequency and for the sake of consistency, 2020 is excluded from both analyzes. Hence, our main model consists of seven variables at a yearly frequency, covering a sample period from 1978 to 2019.

4.2 Quarterly data

Our yearly variables provide us with an overview of the effects of interest, however, the literature review shows that the effects of natural resource extraction are heterogenous across sectors within the economy. Our data source allows us to collect industry-specific data, which we have aggregated and divided into five market sectors: Manufacturing, construction, natural resource extraction, private services, and public administration. A detailed description of included industries in each sector can be found the appendix A. Our quarterly data sample reaches from 1995q2 to 2019q4.

In each sector we investigate predictions of five variables. All variables have been seasonally adjusted by our data source, unless otherwise is specified. Our first variable of interest is production. Production is measured as the gross product in terms of basis value and in million NOK fixed 2019 prices (Statistics Norway, 2022f) Investment is our second variable of interest and is measured as gross investment, and also computed in terms of million NOK fixed 2019 prices (Statistics Norway, 2022g) Our third variable is employment. Here, employment in each sector is computed as the sector-specific number of workers divided by total numbers of workers in all sectors. Average quarterly wage level is our fourth variable of interest and is computed as total gross wage paid out in a sector divided by the number of employees in a given sector and measured in NOK (Statistics Norway, 2022h) Wage has been seasonally adjusted using an Ordinary least squares (OLS) approach, where seasonal dummies constitute the independent variables and the wage series the dependent variable. Residuals from this regression serves as our seasonally adjusted wage series. The productivity level is our last variable of interest and is computed as the gross product divided by total hours worked in the specific sector and measured in NOK. As in our yearly model, oil and gas production and oil price are included using the same units and collected from the same source. The production series has been seasonally adjusted according to the same methodology as for wage.

5. Scenario analysis

In this section, we employ the framework laid out in section 3. We do so under three different scenarios, where we use our yearly data. Each scenario starts with a short description of the scenario and arguments for why we think our conditions are reasonable. Furthermore, all scenarios will provide one conditional and one unconditional forecast. Even though forecasting is not a causal exercise, the credibility intervals allow us to identify statistically significant differences between predictions in the conditional and the unconditional forecast. Hence, the unconditional forecast will act as a baseline scenario throughout our analysis. Even though the unconditional forecast will be identical in each scenario, we will report predictions from it in all three scenarios to make it easier for the reader to follow. After reporting the results from each scenario separately, we discuss the main predictions and implications from them.

5.1 Scenario 1

In our first scenario, we want to predict how the economy is going to respond to a cut in production of fossil fuels, in a case where the cut is in line with achieving the sector-specific goal of reducing emissions towards 2030. As of now, the objective is to reduce emissions from production by 40 percent within 2030, compared to emission level in 2005 (Konkraft, 2020). In according to our data visualized in figure 1,1, the emission level in 2005 made up 15.5 million ton Co2 equivalents. Reducing this amount by 40 percent implies that the level is supposed to be driven down to 8.1-million ton Co2 equivalents by 2030.

Our last datapoint from 2019 for production volume tells us that production amounted to 196.602-million standard cubic meters (Sm3) oil equivalents. Combining this with the emission level in 2019, we find that emissions per Oil equivalent produced amounts to 67 kg Co2 equivalents. Achieving the target would therefore imply that production must be cut by approximately 4.3 percent per year from 2020 to 2030. This means that the production level in 2030 makes up 120.9-million ton Sm3 oil equivalents. In this scenario, we keep the price of oil fixed at 2019 level. Constant price of oil over the 10-year horizon might occur as a consequence of reducing demand in similar fashion as supply. Since the energy transition takes place all over Europe, it is reasonable to assume that households and firms start to substitute energy consumption away from fossil fuels and toward renewable energy. A constant price might, on the other hand, arise as a product of increased production elsewhere, which is a frequently used argument for why reducing fossil fuel production in Norway might induce increased emissions globally.

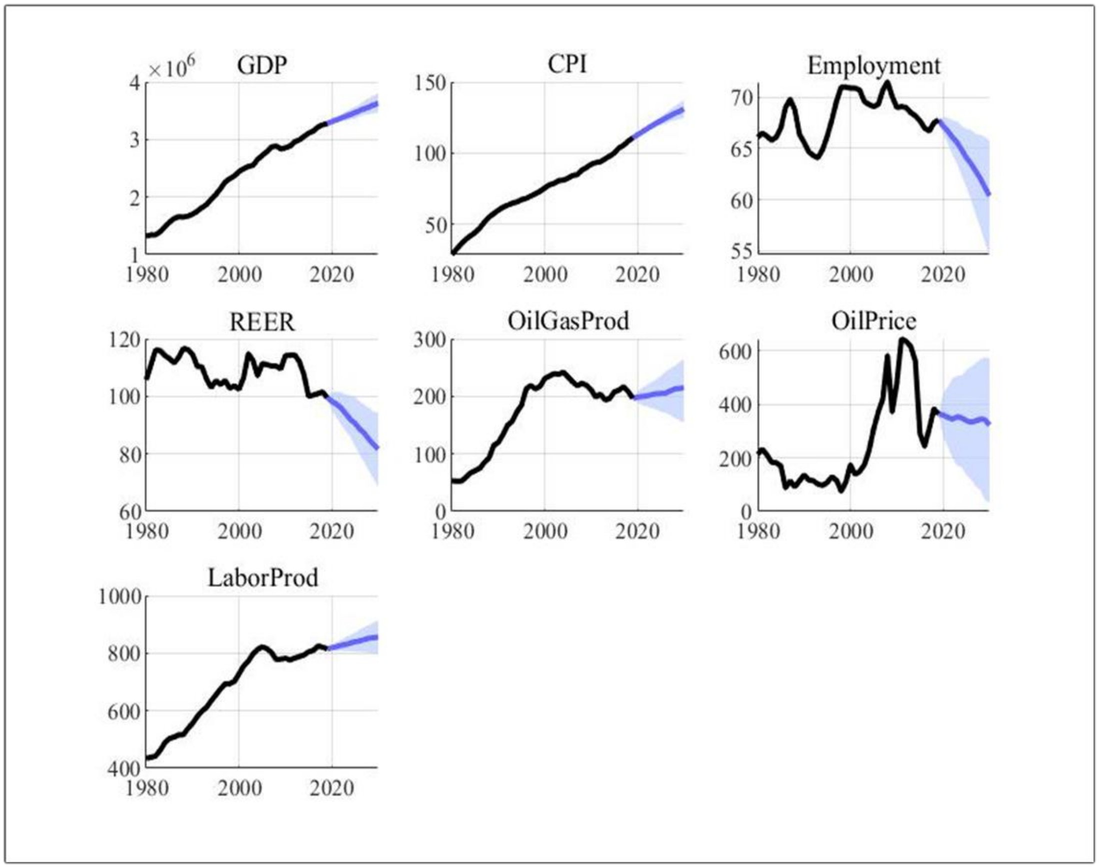

Figure 5, 1. Unconditional forecast. *The median forecast for each variable is given as the dark blue line, which starts in 2020 and ends in 2030. The shaded light blue area represents corresponding 68% probability bands.*

Figure 5,1 and figure 5,2 provides the baseline scenario and the conditional forecast, respectively. Production of fossil fuels is predicted to increase slightly in the baseline scenario. Here, it is supposed to increase from 196 million to 208 million Sm3 oil equivalents, making up an increase of close to five percent. The oil price experiences a small decline from being 364 $ in 2019 to become 357 $ in 2030. Despite from small fluctuations in the price, we believe that this scenario provides a relatively good foundation for investigating the isolated effect of reduced production. Our estimation methodology allows us to obtain five hundred estimates for each forecast horizon in the baseline scenario and in the conditional forecast. We have used this to compute the conditional forecast as a share of the baseline scenario five hundred times. Figure 5,3 provides the median share along with the 68 percent interquartile at each horizon for the five variables of interest. These plots will be referred to as difference plots throughout the rest of the thesis.

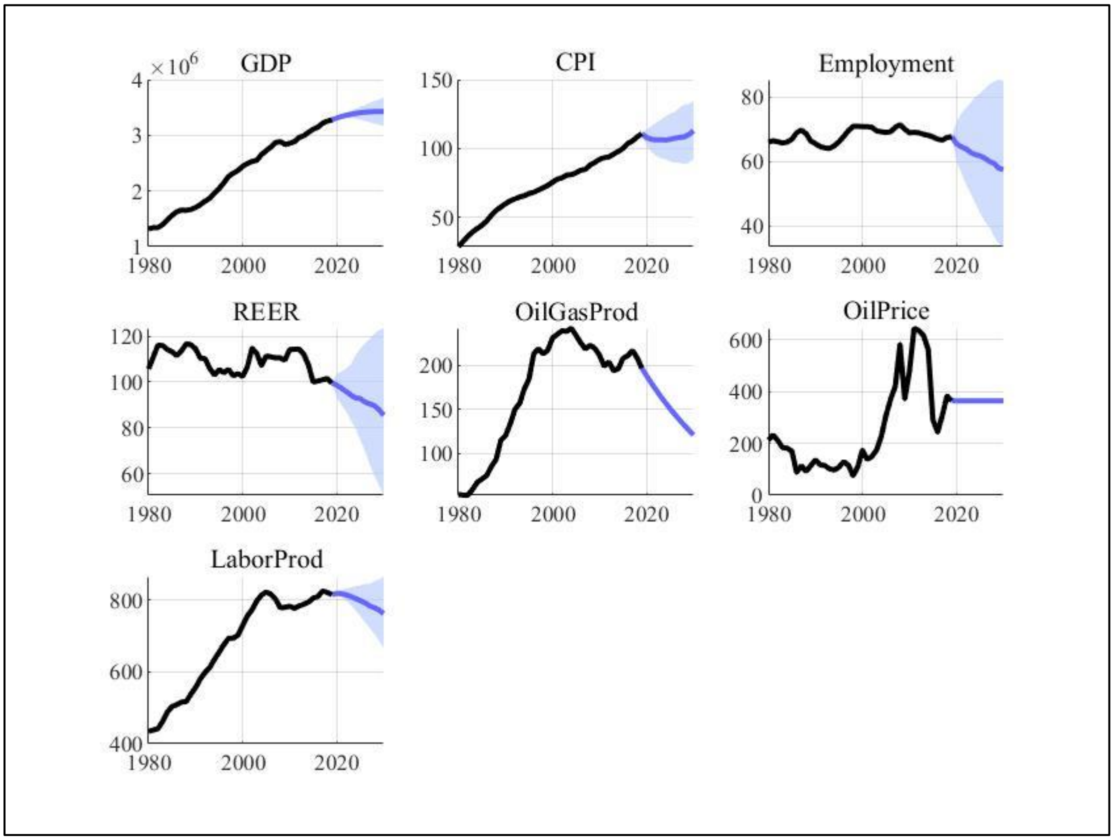

Figure 5, 2. *Conditional Forecast.* The median forecast for each variable is given as the dark blue line, which starts in 2020 and ends in 2030. The shaded light blue area represents corresponding 68% probability bands.

The effect of a cut in fossil fuel production is clearly visible in the GDP level and its growth rate. GDP starts out by increasing toward mid-2020 but flattens out as we approach 2030. In 2020 it grows by one percent. This growth rate is gradually being decreased and is approximately zero in 2030. Hence, the 10-year growth rate only makes up 4.6 percent. The baseline scenario, on the other hand, predicts that the GDP level continues its journey upwards, in line with its historical trend. Here, the growth rate for 2020 is predicted to be one percent as well, but on the contrary to the conditional forecast, is predicted to remain constant over the forecast horizon, and amounts to a 10-year growth rate of 11 percent. In figure 5,3 we see that GDP is predicted to be 5.5 percent lower in the conditional forecast than in the baseline scenario in 2030. Reduced growth seems to have a direct impact on the CPI and causes it to drastically decline, before gradually picking up again towards 2030. The CPI is declining until 2024, experiencing a yearly average deflation rate of 0.8 percent over that period. From then on, is it increasing and ends at a level of 112.9 in

2030. The baseline scenario, per contra, predicts it to steadily increase over the horizon. In comparison to the period where we observe deflationary forces in the conditional forecast, is it predicted an average yearly inflation rate of 1.7 percent in the baseline scenario. It continues increasing towards 2030 and ends at a level of 131. From figure 5,3 we see that the CPI in the conditional forecast in 2030, is 14 percent lower in the conditional forecast compared to the baseline scenario.

Employment is predicted to gradually decline towards 2030, followed by the policy implementation. It starts out at 67.8 in 2019 and ends at 57.6 in 2030, making up a decline of 10.2 percentage points. The path in the baseline scenario is rather similar, but ends at a slightly higher level, 60.4, in 2030. This means that the conditional forecast predicts the policy implementation to induce an additional decrease of 2.8 percentage points in the employment rate and to be five percent lower than the employment rate in the baseline scenario in 2030.

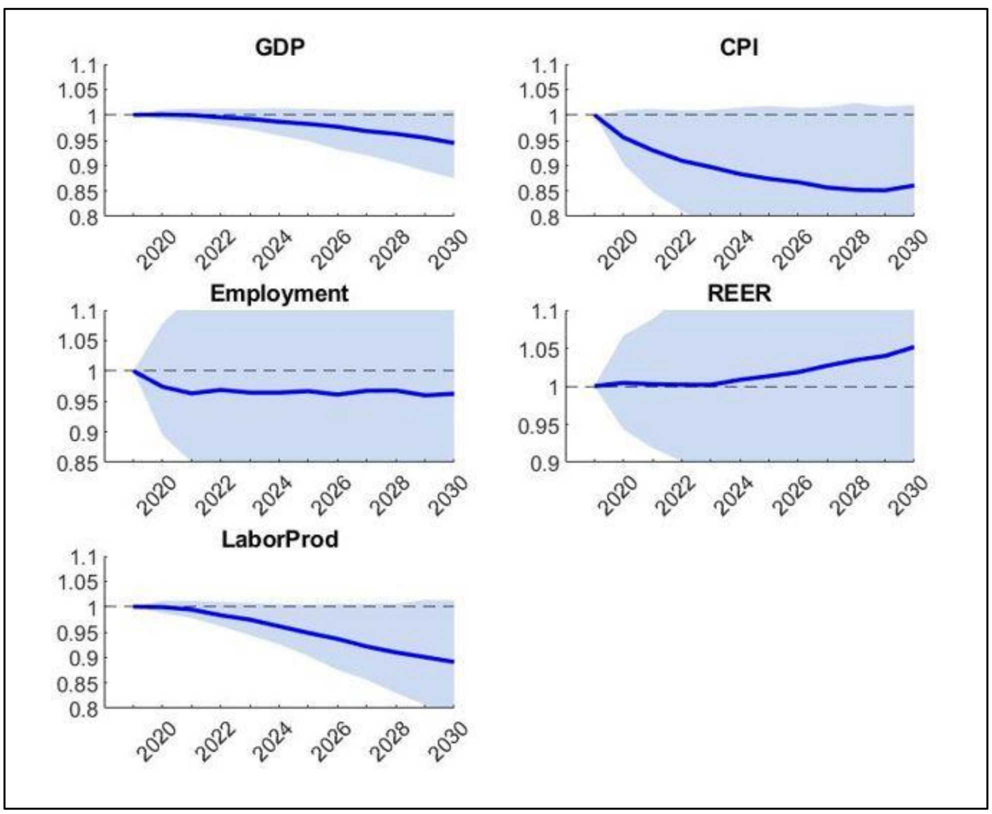

Figure 5, 3. *Difference plot, 2019-2030. The median share of* Conditional forecast-to-baseline scenario at each horizon is given by the dark blue line. The light blue shaded area represents the corresponding 68 % interquartile.

Predictions of the REER share similar characteristics as the ones for the employment rate, as it is predicted to decline gradually towards 2030. Surprisingly, though, it is predicted to depreciate more in the baseline scenario than in the conditional forecast. It starts out at 99.6 and ends up at 85.5 in the conditional forecast, while it ends up at 81.7 in the baseline scenario, making up a depreciation of 14 and 18 percent, respectively. Labor productivity is predicted to experience a substantial decline in the conditional forecast. It starts out at 814.7 NOK in 2019 and gradually declines towards its 2030-level of 762.2 NOK. This level corresponds to the productivity level Norwegian workers had back in 2002. By way of contrast, is the productivity level predicted to reach new heights in the baseline scenario, ending at 856.3 NOK in 2030. Hence, as figure 5,3 illustrates, the productivity level predicted in the conditional forecast barely makes up 90 percent of the productivity level predicted in the baseline scenario.

5.2 Scenario 2

As mentioned in the introduction, the latest report from IPCC underlines that reducing emissions is urgent and that current measures do not suffice to achieve the objective of limiting climate change to 1.5 ℃. More specifically, IPCC estimates that if plans for climate actions around the world remains as specified in 2020, the world temperature will increase by 3.2 ℃ (IPCC, 2022b). This estimate is more than twice as high as the agreed upon limit in the Paris agreement. The United Nations Secretary General, Antonio Guterres, summarized the report with the following statement, “It is a file of shame, cataloguing the empty pledges that put us firmly on track towards an unlivable world” (United Nations, 2022b). Furthermore, the report emphasizes inequality of global heating and a requirement of climate justice and highlight that Europe and North America together, have emitted 40 percent of total emissions since pre-industrial times (IPCC, 2022b).

This implies that Norway, along with the developed world, needs to increase their effort in reducing global emission. Compared to our previous scenario, this one is not based on Norwegian policy goals, but on findings in the latest report published by IPCC. Even though our sample ends in 2019, we do have sector-specific emission data for 2020 available. This enables us to investigate predictions for the Norwegian economy under the assumption that we act in according to the results from the report. In according to IPCC, the world will stand a 50-percentage chance at limiting climate change to 1.5 ℃, if we reduce emissions by 50 percent the next decade (The World Economic Forum, 2022). Furthermore, they expect that industrialized countries take on additional responsibility and should be in the forefront in fighting climate change. Therefore, in this scenario, we assume that Norway cuts sector-specific emissions by 55 percent, compared to 2020 level. This implies a yearly reduction of approximately six percent over our forecast horizon and a production level of 88-million ton Sm3 oil equivalents. This means that the cut in this scenario is extended by 32 million ton Sm3 equivalents, compared to Scenario 1. Oil price is being held fixed just as in the previous scenario and corresponding arguments for why this is the case hold.

Figure 5,4 provides the conditional forecast. Here, we exclude plots showing unconditional forecasts and have left it to appendix D. Figure 5,5 displays the conditional forecast as a share of the baseline scenario.

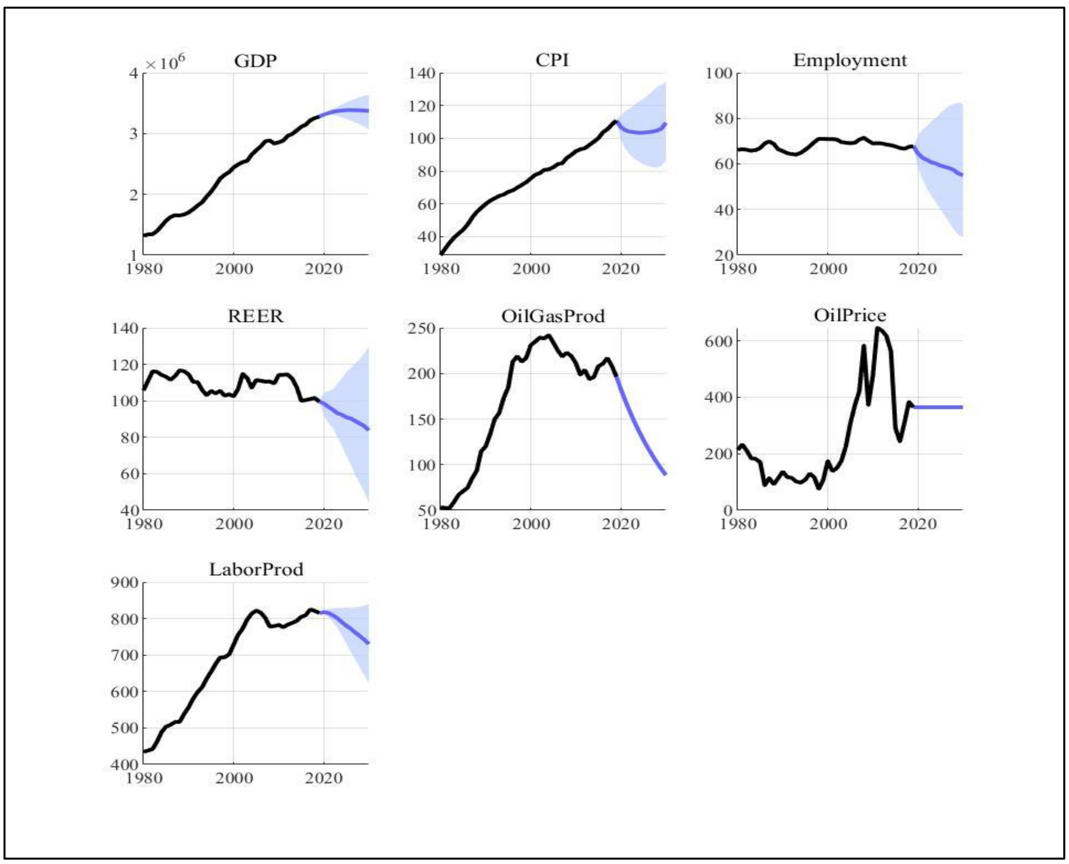

Figure 5, 4. *Conditional Forecast.* The median forecast for each variable is given as the dark blue line, which starts in 2020 and ends in 2030. The shaded light blue area represents corresponding 68% probability bands

The baseline scenario predicts that production fossil fuels will increase slightly towards 2030, just as in the previous scenario. It is predicted to increase from 196 million to 208 Sm3 million oil equivalents in 2030, which is an increase of close to five percent. The oil price decline from 364 $ in 2019 to 357 $ in 2030. This means that the production level in the conditional forecast makes up 43 percent of the production level in the baseline scenario in 2030.

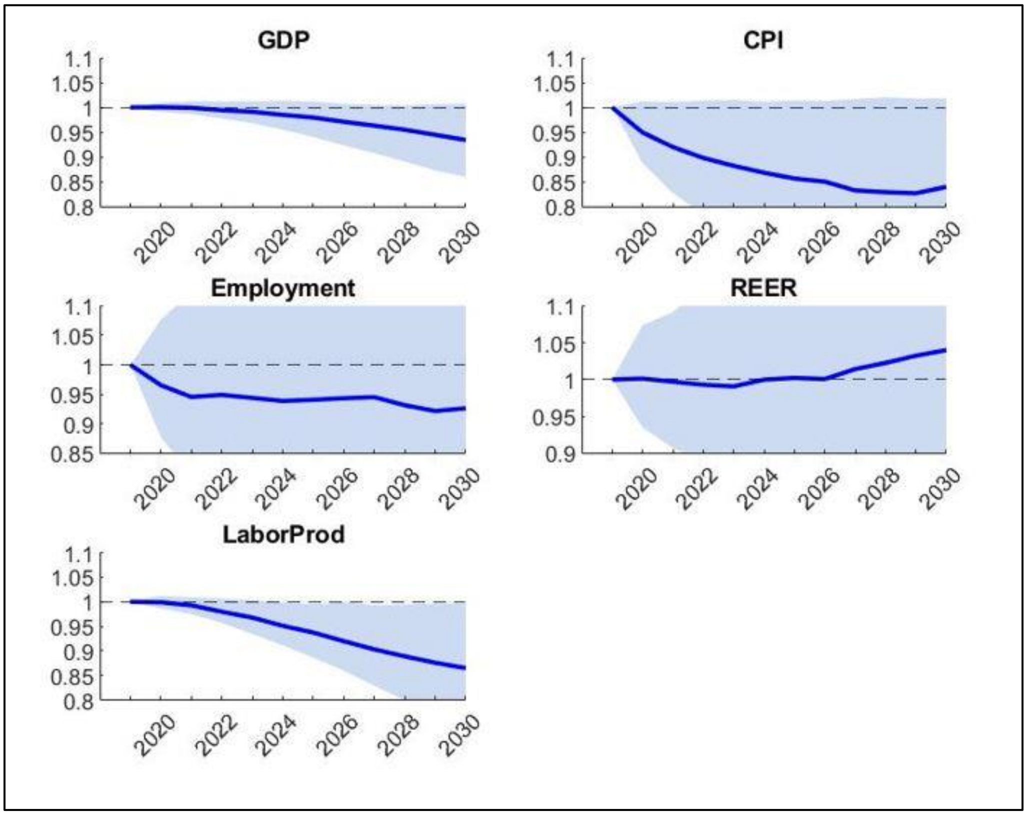

Figure 5, 5. *Difference plot, 2019-2030. The median share of* Conditional forecast-to-baseline scenario at each horizon is given by the dark blue line. The light blue shaded area represents the corresponding 68 % interquartile.

By inspecting the conditional forecast for GDP, we see that it is predicted to increase slightly towards 2025, before it slows down as 2030 approaches. The growth rate in 2020 is still one percent as in Scenario 1. However, the effects are predicted to be more severe in this scenario, and even induces a growth rate of negative 0.2 percent in 2030. Overall, the 10-year growth rate makes up 2.8 percent. The baseline scenario, as expected, predicts that the GDP level continues upwards its long-term trend, and increases by 11 percent over the forecast horizon. From figure 5,5 we see that the GDP level is 6.5 percent lower in the conditional forecast than in the baseline scenario, meaning that the GDP level is 1.1 percentage points lower in this scenario compared to Scenario 1. The CPI starts out at 110.8 in 2019 and is once more predicted to decline towards 2024. Average yearly deflation in this period amounts to 1.4 percent. As we arrive mid-2020's, it starts to pick up again and reach a level of 109.5 by 2030. The baseline scenario predicts it to increase, and inherent yearly average inflation rate of 2.2 percent until 2024. It continues to increase and reaches a level of 131.1 in 2030. From figure 5,5 we see that the CPI in the conditional forecast is 16 percent lower than the CPI in the baseline scenario, which is two additional percentage points compared to what we found Scenario 1.

Employment experiences a steady decline over the horizon in the conditional forecast. The employment rate starts out at 67.8 in 2019 and is reduced to 55.1 by 2030. This means that employment is being reduced by 12.7 percentage points over the forecast horizon. The baseline scenario predicts the rate to be at 60.4 in 2030. From figure 5,5 we see that employment in the conditional forecast is 7.3 percent lower than employment in the baseline scenario. Hence, the employment rate is predicted to decline 2.3 additional percentage points in this scenario compared to Scenario 1. The REER is also predicted to decline gradually in both forecasts. It starts out at 99.5 in 2019 and is driven down to 83.8 in 2030, making up a depreciation of 15 percent in the conditional forecast, while the depreciation constitutes 18 percent in the baseline scenario. Note that, here, the paths provided by the conditional forecast and the baseline scenario are closer to each other than in the previous scenario. At last, labor productivity starts out at 814.7 NOK in 2019 and is reduced to 742 NOK by 2030, meaning that the productivity level is being pushed back to a level that corresponds to productivity in 2000. The baseline scenario predicts the productivity level to reach 856.3 NOK in 2030. In this scenario, the conditional forecast predicts the productivity level to make up 86 percent of that being observed in the baseline scenario, meaning that Scenario 2 induces a reduction of four additional percentage points, compared to Scenario 1.

5.3 Scenario 3

In this scenario we build upon Scenario 2 by using the same production level, but extend it by assuming that the oil price is increasing over the forecast horizon. Such a development might occur for a number of reasons. The Norwegian production of oil constitute close to two percent of world supply (Norsk Petroleum, 2022b), meaning that our imposed reduction in production volume, will lower world supply by approximately one percent. There is a large literature on the short-to medium-term price elasticity of oil supply. See for instance, Baumeister and Hamilton (2019) and Kilian and Zhou (2019) for contributions. However, using these estimates to predict how the price develops under the relatively slow transition that we are investigating is challenging, as policy changes are largely anticipated. Hence, we disregard these estimates and assume that the oil price increases by 50 percent over the forecast horizon. This corresponds to an annual increase of close to four percent.

We believe that such a development is realistic. More than one third of fossil fuel supply is produced by well-developed countries. If these countries take on the responsibility that UN requires them to, and world demand stays constant, reducing world supply by one third could potentially generate a price increase of 50 percent. Furthermore, a report newly published by the International Institute for Sustainable Development (IISD) shows that developed countries must cut output of fossil fuels by 74 percent, and less developed countries by 14 percent, in order to track the 1.5-degree path suggested by the IPCC (Calverley & Anderson, 2022). By doing a weighted average, we obtain a reduction in fossil fuel production by approximately one third. Note, though, that the strategy from IISD implies an enormous reduction by well developed countries, like Norway, and deviates substantially from the objective set by the government towards 2030. Hence, we find it unrealistic to impose such a condition on Norwegian production and stick to the condition proposed in the previous scenario.

Even though well-developed countries do not fully implement the cut suggested by IISD, we believe that there will be additional factors that can draw the price in the direction proposed by us. First, the transition from fossil fuels to renewable energy takes time. In the time interval in between shutting down fossil fuel facilities and building new ones for renewable energy, there might be periods of energy deficit, which might drive up the demand and price of fossil fuels. Second, renewable energy production is weather dependent. In periods of non-suitable weather conditions, the need for alternative energy sources might appear, and the price of fossil fuels might increase. Third, electrifying the energy market will require a lot of minerals, like copper, silver, and aluminum. It is reasonable to assume that equipment used for mineral extraction still depends on fossil fuels by 2030, and that increased extraction increases demand for fossil fuels. At last, developing countries are on the march forward and a major share of these would likely require more fossil fuels as they develop towards 2030 (Calverley & Anderson, 2022).

The baseline scenario is provided in appendix D and the conditional forecast is provided in figure 5,6, while the conditional forecast as a share of baseline scenario is displayed in 5,7. The production level of fossil fuels is predicted to increase in the baseline scenario. The level starts out at 196 million in 2019 and ends at 208-million Sm3 oil equivalents in 2030, making up an increase of six percent. The oil price, however, in which starts at 364 $ per Sm3 oil equivalent, is predicted to decline slightly toward 2030, ending at 357 $. Hence, the production level in the conditional forecast makes up 43 percent of the one predicted in the baseline scenario, while the price level in the baseline scenario makes up 65 percent of the price level imposed in the conditional forecast in 2030.

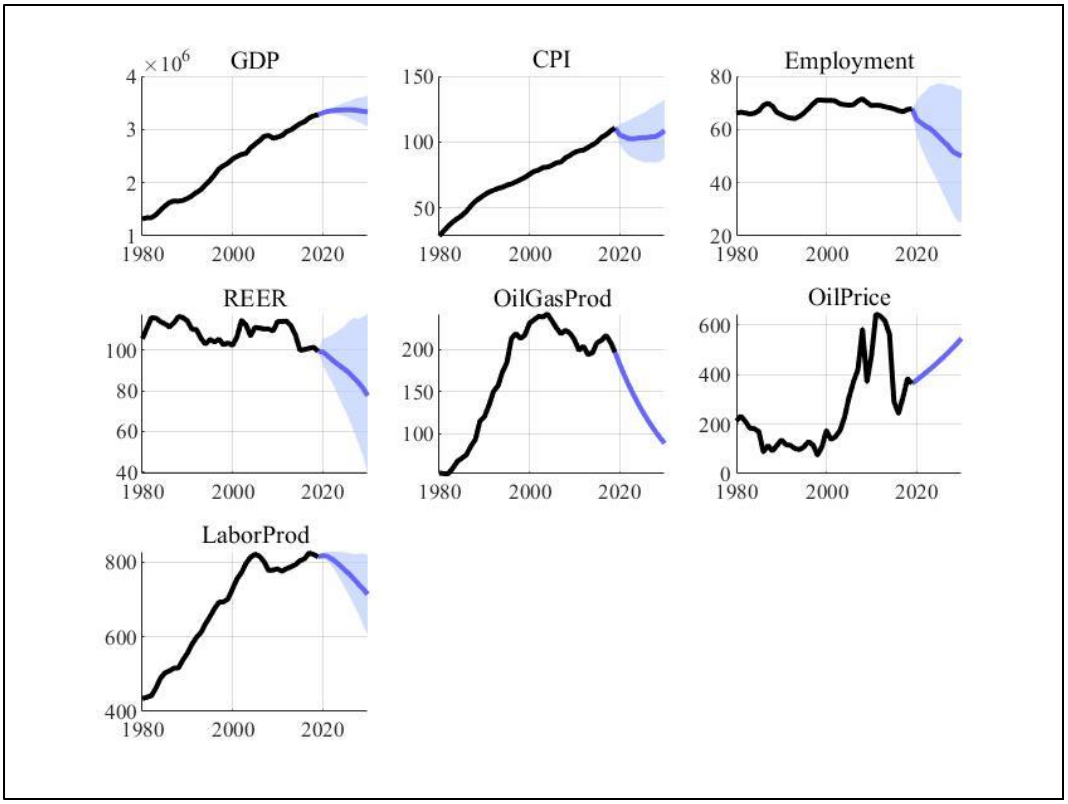

Figure 5, 6. *Conditional Forecast.* The median forecast for each variable is given as the dark blue line, which starts in 2020 and ends in 2030. The shaded light blue area represents corresponding 68% probability bands.

GDP is predicted to increase according to its historical trend and is predicted to have a 10-year growth rate of 11 percent in the baseline scenario. Both forecasts predict annual growth rate to be one percent in 2020, then, the conditional forecast starts to deviate and starts to flatten. The annual growth rate in 2030 is negative 0.3 percent, implying that the oil price increase does not have any dampening effect on GDP. Comparing this to the previous scenario, where price where held constant, we observe that the negative growth in 2030 is actually amplified by 0.1 percent in this scenario. Furthermore, the conditional forecast predicts the 10-year growth rate in GDP to be 1.6 percent in this scenario, which is approximately two thirds of the predicted growth rate in the previous scenario, implying that increased oil price has a negative impact on the economy. This is confirmed in figure 5,7, where the GDP level in the conditional forecast is 7.2 percent lower than the GDP level observed in the baseline scenario. Hence, the conditional forecast is 0.7 percentage points lower in Scenario 3 than in Scenario 2.

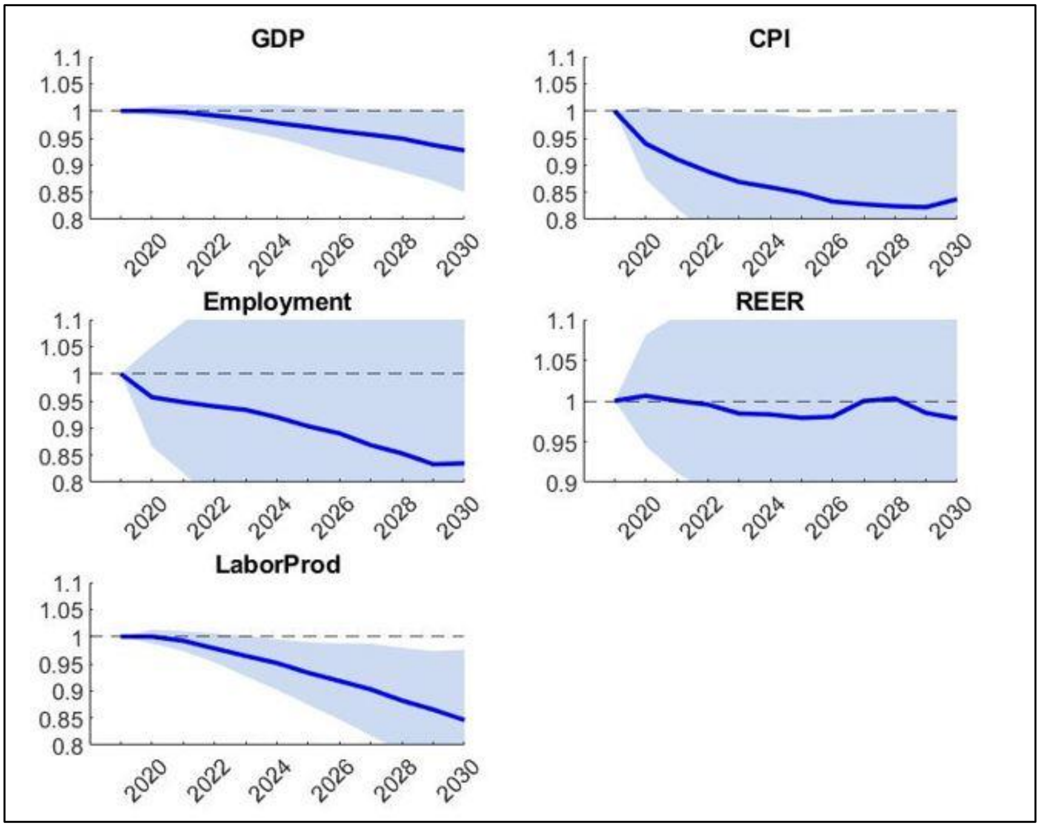

Figure 5, 7. *Difference plot, 2019-2030. The median share of* Conditional forecast-to-baseline scenario at each horizon is given by the dark blue line. The light blue shaded area represents the corresponding 68 % interquartile.

The CPI starts out at 110.8 and then adopt deflationary characteristics in the conditional forecast. Deflation will be at its highest in 2020, reaching annual deflation rate of five percent. Average annual deflation rate in the interval 2020-2024 amounts to 1.4 percent, which is equivalent to the deflation rate predicted in the previous scenario. In this scenario, though, the CPI declines more early on, but recovers one year before compared to the case where oil price is held constant. It does, however, end up being lower in this scenario compared to Scenario 2 in 2030. Figure 5,7 shows that the CPI in the conditional forecast is 16.3 percent lower than in the baseline scenario in 2030, meaning that the CPI is 0.3 percentage points lower in this scenario compared to Scenario 2.

The baseline scenario predicts that the employment rate will gradually decline towards 2030. It starts out at 67.8 in 2019 and is being predicted to decrease to 60.4 by 2030, i.e., a reduction of 7.4 percentage points. Predictions from the conditional forecast share similar characteristics but decrease even further over the forecast horizon and ends at 50.6, making up a negative decline in employment of 17.2 percentage points. From figure 5,7 we see that employment in the conditional forecast is 16.5 percent lower than in the baseline scenario. Hence, compared to Scenario 2, the employment rate is 9.2 percentage points lower in this scenario, implying that the price increase affect employment negatively as well.

The REER starts out at being 99.5 in 2019. The conditional forecast predicts it to decline gradually and reach 78.9 by 2030, making up a depreciation of 20 percent. At the same time, the baseline scenario predicts it to depreciate by 17.6 percent, and to be at level of 81.9 in 2030. Hence, the conditional forecast predicts an additional depreciation of 3 index points. Unexpectedly, the REER tends to depreciate more when we increase the oil price and is for the first time predicted to depreciate more in the conditional forecast than in the baseline scenario. Finally, labor productivity falls from 814 NOK in 2019 to 723 NOK in 2030 in our conditional forecast, while it is predicted to increase to 856 NOK in the baseline scenario over the same horizon. Hence, productivity of workers is being pushed back to 1999 level and as figure 5,7 illustrates, constitute 84 percent of the productivity level predicted in the baseline scenario in 2030. Hence, the productivity level in this scenario is predicted to be two percentage points lower than the productivity level in Scenario 2.

5.4 Results from Scenario 1,2, and 3

All three scenarios predict that the growth rate in GDP stagnates towards 2030, and to even turn negative in the two most recent ones. Bjørnland et al. (2019) pointed out the petroleum sector as an important factor in ensuring growth in the domestic economy. The fact that our model predicts that reducing production of fossil fuels by half over a 10-year horizon, cause the GDP level to decline implies that the sector is indeed an important factor for growth. This could be due to diminishing productivity spillovers, caused by reduced activity in the fossil fuel sector towards 2030. This view is also supported by predictions for the productivity level, which is predicted to be pushed back to productivity levels observed around 2000. Moreover, our predictions for GDP and productivity level are in line with results found in Bjørnland et al. (2019), who estimate that activity shocks tend to explain a substantial amount of the variation in both domestic GDP and productivity level two years after the shock occurred. Results from Bjørland and Thorsrud (2016) does, on the other hand, imply small effects in the price level followed by an activity shock. This is not what we find when imposing our long-term conditions. All three scenarios predict the CPI to decline drastically early on, but then to start increasing as we reach mid-2020. Parts of this can be explained by reduced activity. Note, though, that the CPI responds more powerfully early on compared to GDP. This might reflect the forward-looking nature of inflation. When the government announces the policy implementation in 2019, employers and employees downgrade their expectations of future economic activity. This could potentially affect the wage and price formation already today. This effect might be particularly strong in Norway, as wage bargaining is done according to Frontfagsmodellen (Norsk Industri, 2022), which will ensure that the domestic wage level will follow competition exposed sectors.

The resource movement effect from Dutch disease theory predicts that any changes in the resource sector will cause movements in the labor force. Hence, in our analysis we could expect that workers will flow out from the fossil fuel sector and towards other sectors in the economy. Scenario 1 predicts that the policy implementation would cause an additional reduction in employment of 2.8 percentage points. Whether reduced employment is due to reducing employment in the sector itself, or due to reduced activity in the overall economy is not clear. However, we do know that the fossil fuel sector hires approximately seven percent of the labor share. Reducing production by 43 percent, as we did in this scenario, we would expect employment to decline by 2.3 percent, implying that employment reductions are mainly due to reduced employment in the sector itself. In scenario 2, we impose further restrictions on production and reduce it by 55 percent. This resulted in employment dropping by five percentage points. If employment were to track activity, we would have expected a reduction of 3.85 percentage points. Hence, in according to our model, employment responds more than one-to-one to activity after a certain threshold, i.e., employment tracks production relatively well, but seems to generate repercussions in the domestic economy as the size of the cut increases. That being said, since the growth rate in overall GDP stagnates over the horizon, it is more likely that reduced employment is a combination of reduced domestic labor demand and labor demand from the sector itself.

Scenario 1 and 2 suggests that production volume has small effect on the REER, as the REER is predicted to depreciate more powerfully in the baseline scenario in both cases. Theories reviewed in earlier sections suggests that the REER can move in both directions followed by an activity shock and that it will depend on the relative strengths of the resource movement and the spending effect. Previous empirical findings from Norway suggest small effects in the REER followed by positive resource shocks but observe signs of real appreciation. We would therefore expect the REER to depreciate in response to reduced activity in the fossil fuel sector. This is not what we observe. Note, though, that the REER depreciates more in Scenario 2 than in 1, suggesting that reduced production pulls in the direction of depreciation, but to a small extent. Hence, our predictions 10 years ahead might be considered surprising when investigating the effects through the lens of Dutch disease models. There is, however, a large literature on the determinants of the long run real exchange rate, where government spending, current account imbalances, and interest rates differentials are being emphasized as important drivers. See Rogoff (1996) for survey. Moreover, this provides us implications for the spending effect in the Norwegian economy and that it seems to be small. This can be rationalized by policy rules for how to spend revenues generated from fossil fuels and the fact that income from this sector is transferred to the pension fund and not directly into the economy. This will dampen the effects of reduced income from fossil fuel production, as policy rules ensures stable use of income throughout the whole period. On the other hand, above we stressed the large effect observed in the CPI and that it declines early on. This implies that the spending effect is present and rather strong. Hence, we have two opposite implications for the spending effect and cannot conclude, based on our predictions, in which direction it moves in the economy. We may, however, conclude that our model predicts the relationship between REER and CPI to be weak.

Comparing our results to the results from the strictest scenario in Aune et al. (2020), we see that the direction of the macroeconomic effects is similar, but that the results found in our analysis is amplified for all variables. They predict that GDP will grow at an average annual growth rate of 1.27 percent between 2023-2030. Our analysis predicts the same rate over the same horizon to be 0.2 percent in Scenario 1, and even smaller in the subsequent scenarios. Moreover, Scenario 1 predicts that average annual inflation will amount to 0.17 percent in the time interval 2020-2030, which is far less than two percent, as predicted in their paper. They predict that employment is going to grow on average by 0.49 percent annually in the period 2023-2030, whereas Scenario 1 in our analysis predicts the employment share to get reduced by 0.74 percent each year in the same time interval. At last, they predict that labor productivity will grow on average by somewhere in between one and 1.4 percent annually in the time interval 2023-2030, while Scenario 1 in our analysis predict the corresponding rate to be negative 0.82 percent.

Bigger effects in our analysis are expected, as we impose larger activity reductions compared to them. Another contributing factor to this result is that we do not take into account the effects of fiscal and monetary policy. As they pointed out, Norges bank will most likely respond by lowering the policy rate as the activity is being reduced. This will dampen the effect of reduced demand in the overall economy. Furthermore, it will cause the REER to depreciate, through a weakening of the nominal exchange rate. This will improve the competitiveness of the Norwegian economy and facilitate a smoother reallocation of input factors towards other sectors. Hence, the exclusion of policy variables might be an important explanation for why we observe large effects in some of the variables, like GDP, CPI, and employment, but also for why we observe small effects in others, like the REER. Moreover, our estimated VAR does not satisfy the stability condition. This might be another reason for why we observe large effects in some of our variables. Appendix C provides results from an analysis where Scenario 1 is conducted using a stable model. The results support our predictions for GDP and Employment in the main analysis, while predictions for CPI, labor productivity, and the REER are of a lesser size in the stable model.

Finally, in Scenario 3 we extended Scenario 2 by introducing an increase in the price of oil. Our model predicts that an increasing oil price in general is hurtful for the economy, as it reduces activity, productivity, and employment. This is in line with theory and empirical findings in Bjørnland and Thorsrud (2019). A possible explanation for why we observe this is that oil is still a crucial factor in production and makes up a substantial share of household's energy consumption (Energi Norge, 2021). Increasing the price of oil would therefore increase the production cost of firms, and at the same time, reduce the purchasing power of households. These effects combined, draws in direction of reduced demand, which lowers activity and employment. We do, however, observe that the real exchange rate tends to depreciate more followed by increased price. This is opposite of what is being predicted by the Dutch disease literature. Again, it might imply that the spending effect in the Norwegian economy is to a large extent absent. However, as a commodity currency, one would have expected that when increasing the price, it would have improved the Terms of Trade and caused the REER to appreciate. Throughout all three scenarios production and price of fossil fuels does not seem to explain a substantial share of the variation we observe in the REER, and implies that other factors are more important in determining the long-term real exchange rate.

6. Sectoral Analysis

This section extends Scenario 1 investigated in subsection 5.1. We do so by considering predictions for market sectors in the Norwegian economy. Literature reviewed above, showed that the effects from the fossil fuel sectors are heterogenous across sectors. We find these effects particularly interesting and crucial to understand, if we are to fully comprehend the role of oil and gas sector in the Norwegian economy. Hence, we dive deeper into the Norwegian economy and proceed by predicting how our five sectors performs. Note, though, that we will limit ourselves to investigating manufacturing, construction, and private services, as these sectors are the most important for the theory. Predictions for natural resource and public services sector can be found in appendix E. The imposed condition on production is set such that quarterly production in 2030 will summarize to the yearly production level imposed in Scenario 1.

6.2 Manufacturing

We start by investigating the impact on the manufacturing industry. The unconditional forecast for this sector is presented in figure F,1 in appendix F. The conditional forecast is provided in figure 6,1, while the difference plots are displayed in figure 6,2.

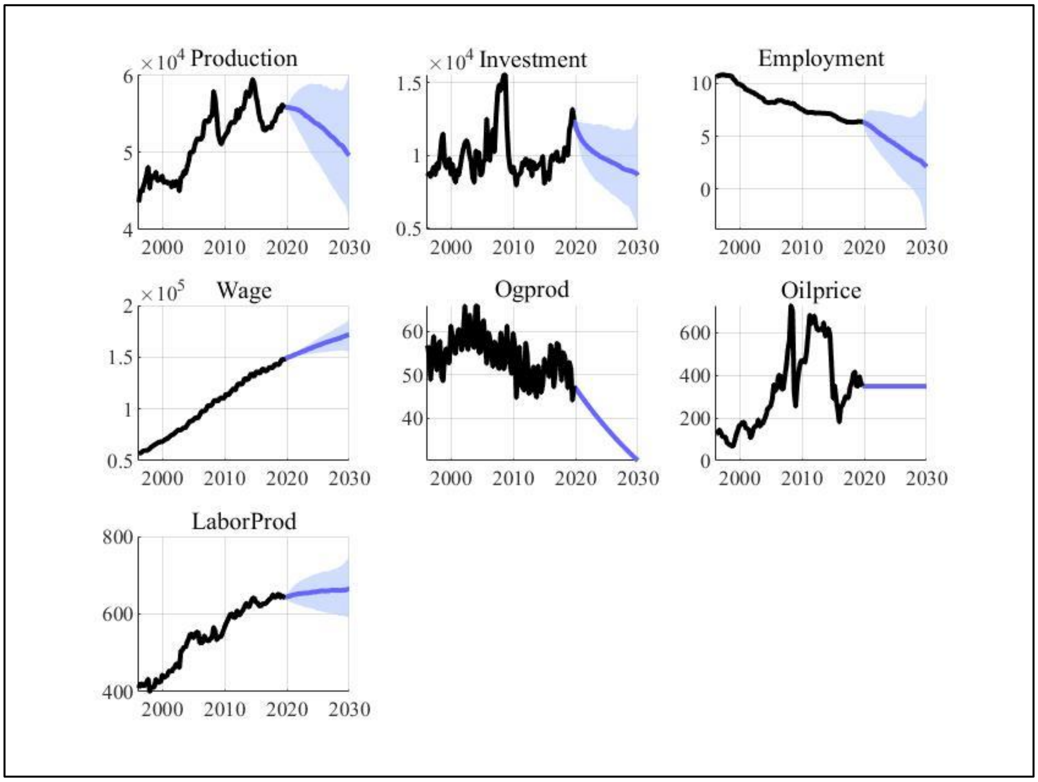

Figure 6, 1. *Conditional Forecast.* The median forecast for each variable is given as the dark blue line, which starts in 2020q1 and ends in 2030q1. The shaded light blue area represents corresponding 68% probability bands.

A cut in production of fossil fuels seems to have rather severe effects on this sector. Production is predicted to drop by 11 percent over the forecast horizon in the conditional forecast, implying an average annual growth rate of approximately negative one percent. The baseline scenario, on the other hand, predicts an average annual growth rate of positive 0.87 percent. By comparing the conditional forecast and the baseline scenario in figure 6,2, we see that production is 14 percent lower in the conditional forecast. Further, Investment falls in both forecasts. The baseline scenario predicts it to drop substantially early on, but to stabilize at a lower level from 2022 and onwards. Hence, the paths track each other reasonably well until 2022 in figure 6,2, but as investment start to stabilize in the baseline scenario, the deviation starts to increase. In 2030, investment in the conditional forecast is 20.1 percent lower than investment in the baseline scenario.

Employment is predicted to keep falling in line with the historical trend, but might undergo the most dramatic change and drop to an unprecedented low level of 2.5 percent in 2030 in the conditional forecast. The baseline scenario predicts it to be at

4.9 percent in the same year, making up a difference of 2.4 percentage points in 2030. As seen in figure 6,6, this decrease is a large share of employment in the manufacturing sector, where employment in the conditional forecast is 50 percent lower than employment in the baseline scenario. We observe that labor productivity shows signs of stagnation in the conditional forecast, but increases slightly from 642 to 665 NOK over the period, making up an increase of 3.5 percent. The baseline scenario predicts it to increase along its historical trend and reaches 752 NOK in 2030. Hence, the productivity level in the conditional forecast is 11.1 percent lower than the productivity level in the baseline scenario.

Given predictions for the productivity level and economic theory, we would have expected the average wage to have similar characteristics. This is not what we observe. Average wage keeps increasing in the conditional forecast, despite stagnating productivity, but does not reach the same level as in the baseline scenario. As visualized in figure 6,2, the difference between average quarterly wage in the conditional forecast and the baseline scenario is small, where it is predicted to be 4.6 percent lower in the conditional forecast in 2030.

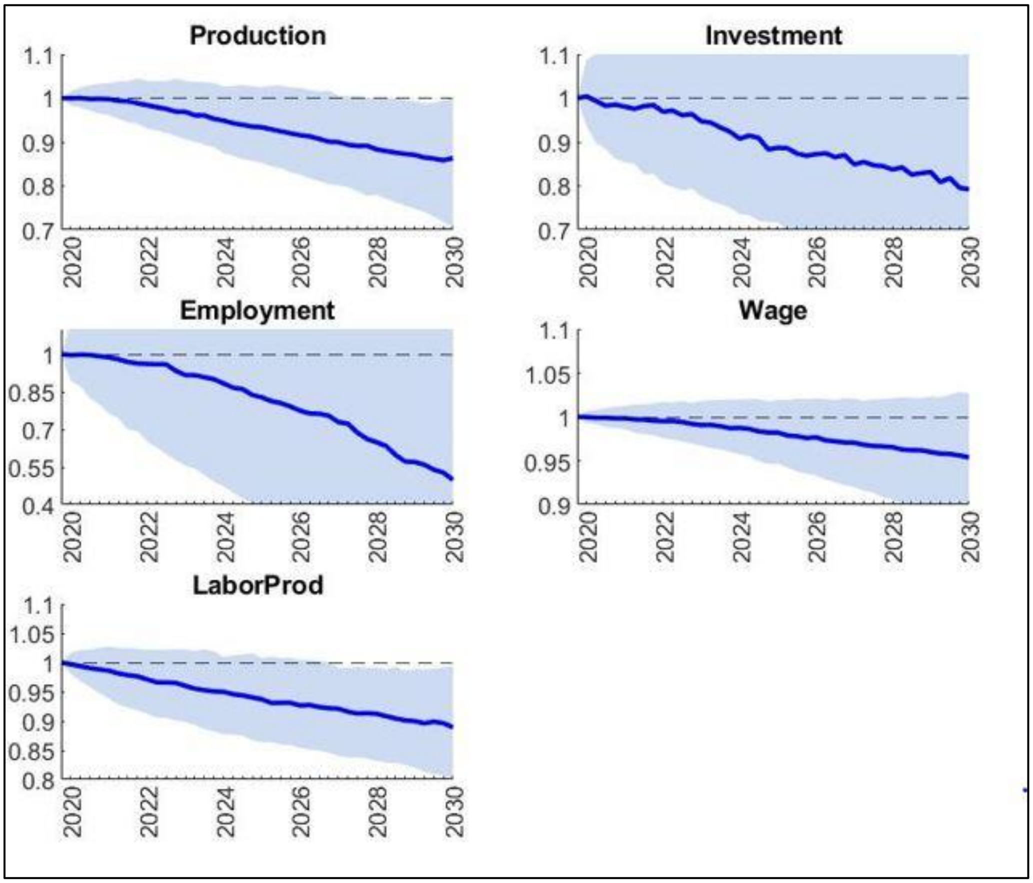

Figure 6, 2. *Difference plot, 2019q4-2030q1. The median share of* Conditional forecast-to-baseline scenario at each horizon is given by the dark blue line. The light blue shaded area represents the corresponding 68 % interquartile.

Our predictions imply fewer people at work and less investment, which means fewer hours worked and a smaller stock of capital due to negative net investment. It translates into less production logically. The stagnating average labor productivity results from a same percentage fall in both hours worked and production. It means that the production process will remain as capital intensive as before. We can assume that wage is set equal to marginal productivity of labor that has augmented only slightly over the forecast period. It seems that the raise in wage is then due to increased hours worked per employee, i.e., there are fewer people at work, but they work overtime and get paid higher salaries.

6.2 Construction

Predictions for the construction sector suggests that manufacturing and construction will follow different paths towards 2030. The conditional forecast is provided in figure 6,3, while the difference plots are shown in figure 6,4. The baseline scenario can be found in figure F,2 in appendix F.

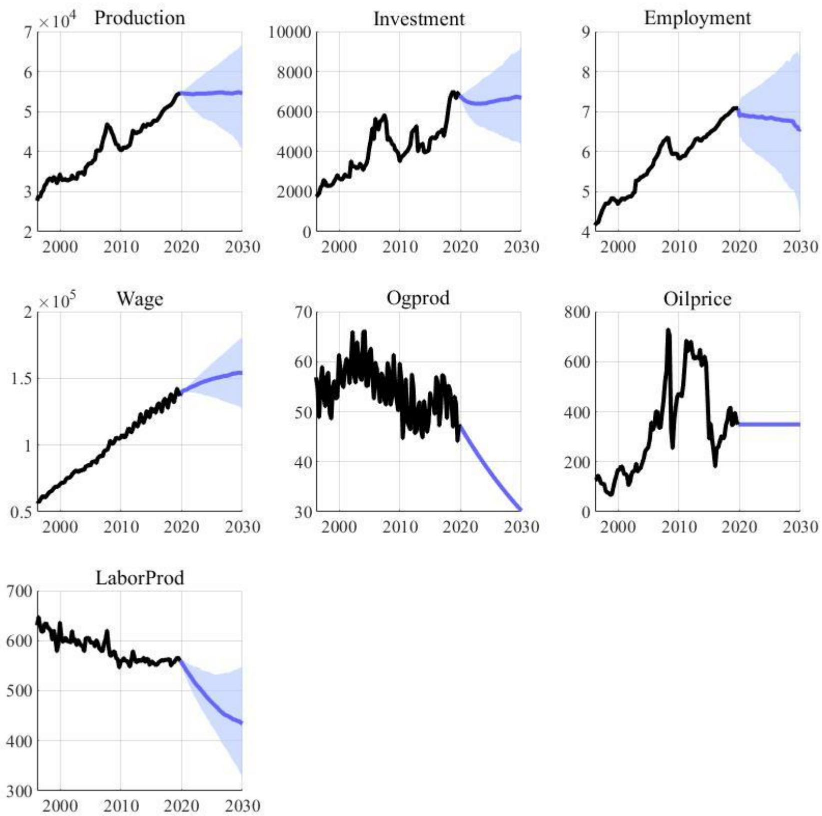

Figure 6, 3. *Conditional Forecast.* The median forecast for each variable is given as the dark blue line, which starts in 2020q1 and ends in 2030q1. The shaded light blue area represents corresponding 68% probability bands.

Production increases by one percentage point towards 2030, while investment drops by two percent over the same period in the conditional forecast, implying that average yearly growth is close to zero for both variables. Note that Investment drops early on but starts to pick up again towards 2030. Production and Investment continue along their upward trends in the baseline scenario, and experience growth of 15.3 and 9.4 percent, respectively. This ensures average annual growth rates of 1.3 and 0.82 percent for Production and Investment. Figure 6,4 visualizes that the production level in 2030 is 11.8 percent, while the investment level is 9.6 percent lower in the conditional forecast compared to the baseline scenario. The employment share of the sector, which has been increasing throughout our sample, will be reduced by one half of a percentage point towards 2030 in the conditional forecast, while it increases by 1.2 percentage point over the same period in the baseline scenario, making up a difference of 1.7 percentage points. As seen in the figure below, this implies that the employment share predicted in the conditional forecast is 19.7 percent lower than the employment share predicted in the baseline scenario.

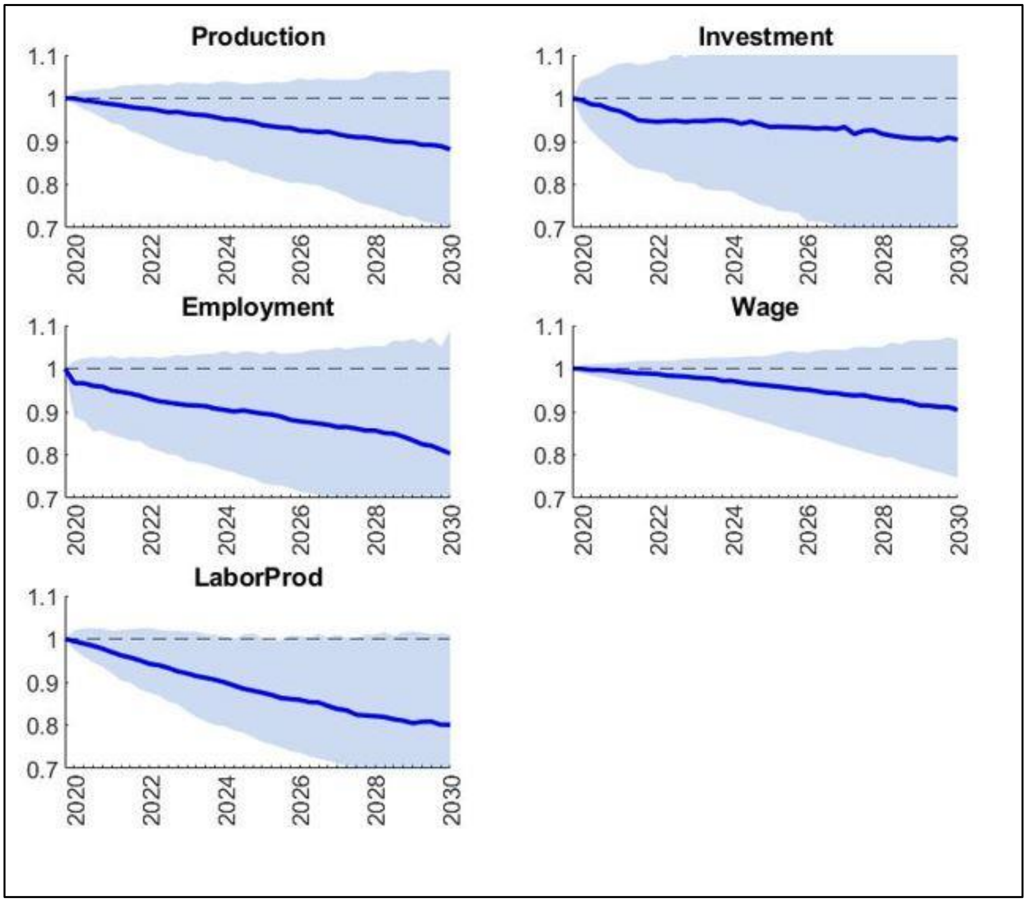

Figure 6, 4. *Difference plot, 2019q4-2030q1. The median share of* Conditional forecast-to-baseline scenario at each horizon is given by the dark blue line. The light blue shaded area represents the corresponding 68 % interquartile.

The average wage will keep increasing, just as in the baseline scenario, but at a slower pace. From the figure above we see that the wage level predicted in the conditional forecast is 9.6 percent lower than the wage level observed in the baseline scenario in 2030. A distinctive characteristic of the construction sector is with regards to labor productivity. The construction sector is the only sector that has experienced a downward-sloping trend in the productivity level in the sample period. Hence, both forecasts predict it to decline, but the conditional forecasts predict that the cut in fossil fuel production will aggravate the decline substantially. The productivity level is predicted to be 431 NOK in the conditional forecast, while it is predicted to be 549 NOK in the baseline scenario. This decline constitutes 23 and 1.8 percent in the conditional and the baseline scenario, respectively. In 2030, we see from figure 6,4 that the productivity level is 19.9 percent lower in the conditional forecast compared to the baseline scenario.

We observe that there is a decline in number of people at work, while the stock of capital remains close to constant. It results into a stagnating production level. We observe a decline in productivity while production is close to stable. It implies increased hours worked in total. Given less people at work, we can state that hours worked per employee has increased. It also explains increasing average wages due to overtime, despite falling marginal productivity of labor.

6.3 Private Services

We now move our attention to the sector of private services. The conditional forecast is displayed in figure 6,5, while the difference plots are shown in figure 6,6. The unconditional forecast is provided in figure F,3 in appendix F. By inspecting figure 6,5, we see that both production and investment keep increasing towards 2030 in the conditional forecast by 9.9 and 7.8 percent, respectively. Production is therefore predicted to increase on average by 0.9 percent annually, while the corresponding rate for Investment is 0.7 percent.

Nevertheless, the growth rate in both variables will slow down relatively to the baseline scenario. Production and Investment increases by 16.5 and 11.8 percent in the baseline scenario, respectively. This corresponds to average annual growth of 1.4 and one percent for Production and Investment. As observed in figure 6,6, Production and Investment is 5.5 and 2.8 percent lower in the conditional forecast than in the baseline scenario, respectively. Hence, the fossil fuel sector seems to impact the activity level in private services as well. However, the biggest impact is observed in the employment share. It drops from 58 percent to approximately 44 percent under the effect of a cut in fossil fuel production, while it is estimated to go down by 1.4 percent in the baseline scenario. As observed in figure 6,6, the employment share in the conditional forecast is 23 percent lower than the employment share predicted in the baseline scenario.

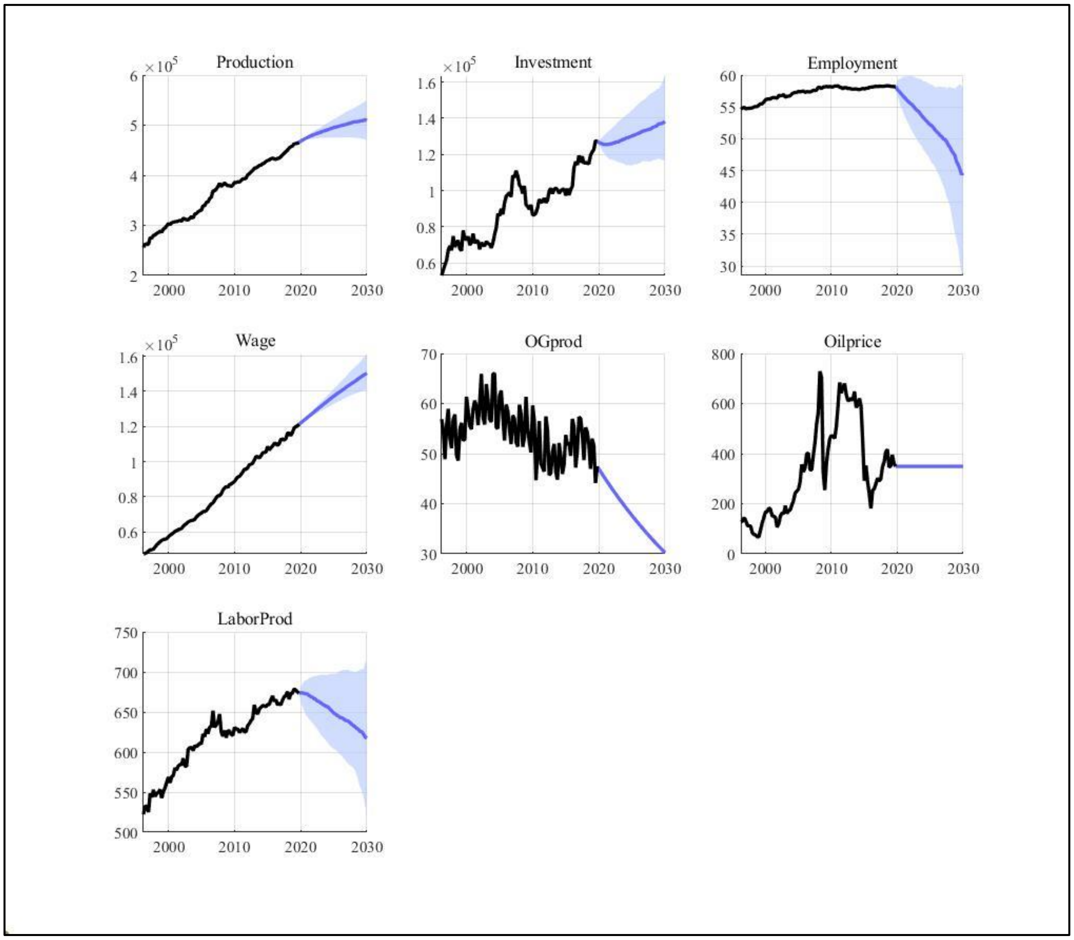

Figure 6, 5. *Conditional Forecast.* The median forecast for each variable is given as the dark blue line, which starts in 2020q1 and ends in 2030q1. The shaded light blue area represents corresponding 68% probability bands

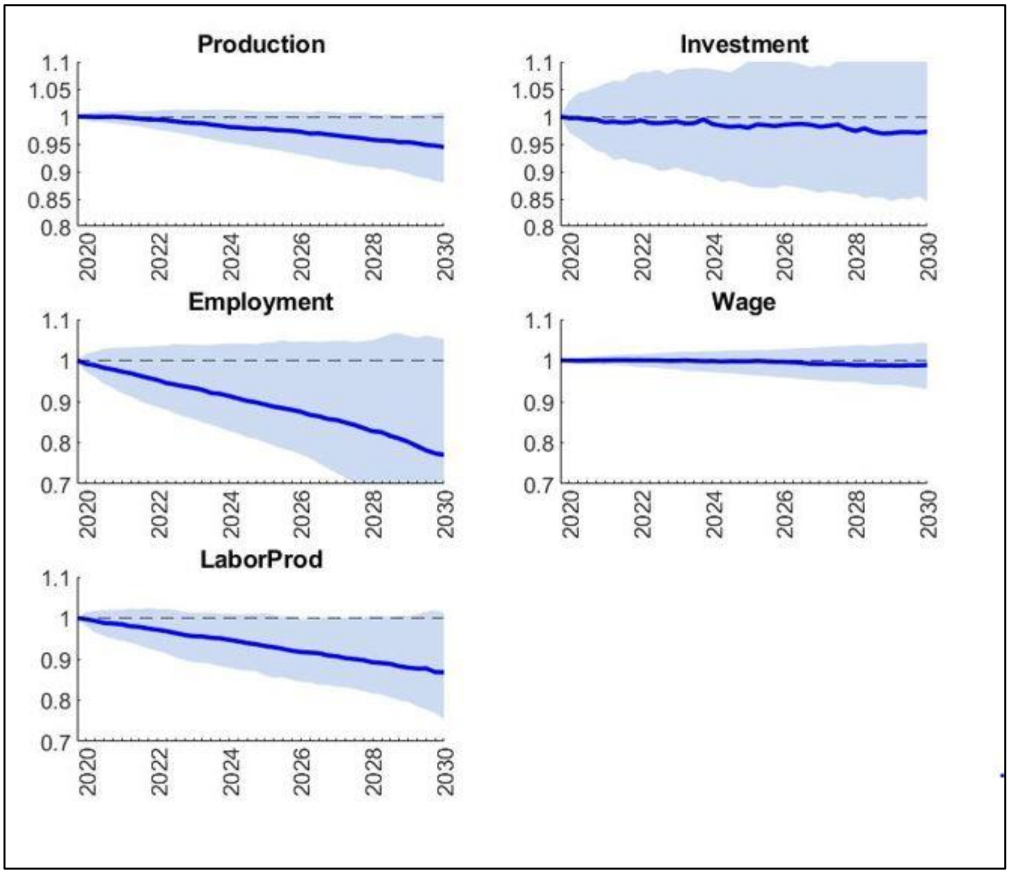

Figure 6, 6. *Difference plot, 2019q4-2030q1. The median share of* Conditional forecast-to-baseline scenario at each horizon is given by the dark blue line. The light blue shaded area represents the corresponding 68 % interquartile.

Labor productivity will suffer as well. Our model predicts it to reach 708 NOK in the baseline scenario, while to reach 617 NOK in the conditional forecast. This corresponds to a reduction of 8.3 percent in the conditional forecast, and an increase of five percent in the baseline scenario. Figure 6,6 visualizes that this corresponds to labor productivity that is 13.2 percent lower in the conditional forecast than in the baseline scenario in 2030. The average wage level, however, is hardly affected by reduced activity in fossil fuel sector, where the wage level observed in the conditional forecast makes up as much as 99 percent of the one observed in the baseline scenario. In this case, this can partially be explained by opposite movements in Production and Employment, which leaves wage largely unaffected. Despite a serious decline in both employment share and labor productivity, both production and investment seem to keep increasing following the cut in fossil fuel production, which means that this sector performs relatively well compared to previous sectors.

We observe falling productivity while there is only a slight decrease in production. It implies an increase in total hours worked. But there are fewer people at work at the same time. It requires an increase in hours work per employee again, equivalent to overtime work. Overtime work drives the wage increase, despite a decline in marginal productivity. The wage level is the same as in the baseline while total hours worked have increased. It means therefore a drop in average hourly wage compared to baseline outcome in 2030.

6.4 Results from the sectoral analysis

Our sectoral analysis has shown us that all three sectors are positively related to the fossil fuel sector, but to a varying degree. When investigating relative impact on the sectors, we do so by considering the difference between the conditional forecast and the baseline scenario in each sector, and then compare these differences across sectors. Our findings suggests that manufacturing is the sector that experiences largest negative impact followed by reduced fossil fuel production. Predictions for this sector generates the largest difference between the baseline scenario and the conditional forecast in terms of Production, Investment, and Employment. The impact is substantial in the construction sector as well, which experiences the largest impact in terms of labor productivity and wage level among the sectors. Private services are also predicted to see negative impacts in all of the variables, but performs relatively well in our analysis and is first and foremost experiencing large impact in its employment share.

Manufacturing and construction seem to be heavily dependent on the fossil fuel sector. Reduced activity in both sectors imply that both sectors are important indirect suppliers of the fossil fuel sector. Therefore, reduced activity in the fossil fuel sector leads to lower demand and engenders contractionary effects in the two aforementioned sectors. The policy implementation reduces the number of profitable investments and forces the less productive firms out of the sectors, as well as forcing firms to lay off workers. Another indirect transmission channel is the public demand. We know that the construction sector is dependent on public demand. When the government decides to reduce fossil fuel production, they might respond by demanding less from the construction sector as a result of less income in the future.

These results are to some extent in line with empirical findings in Bjørnland and Thorsrud (2016), however, we find that manufacturing is more impacted than the construction sector, as contrary to them. Hence, assuming that construction is the non-tradeable sector and manufacturing the tradeable sector, it seems like the tradeable is more affected than the non-tradeable sector, which is opposed to traditional Dutch disease theory, but very much in line with findings in Bjørnland et al. (2019). We observe reduced productivity in these two sectors over the forecast horizon, implying that the fossil fuel sector has strong LBD effects and that the spillovers from these to manufacturing and construction, are diminishing as we reduce its activity level.

Employment tends to decrease substantially in private services. A potential explanation could stem from the fact that a big share of private services is somehow connected to the fossil fuel sector, and in particular the financial sector Hernes et al. (2021). Reducing its activity might force employers in the financial industry to reduce the number of jobs aimed towards the fossil fuel sector, while keeping production and investment growth positive by finding profitable investments elsewhere. Another explanation is the fact that many low-paid positions in the sector are filled with immigrant workers. Following a decline in the exchange rate after the export cut and fearing a drop in their real wages, many of them might quit their jobs and leave their vacant. Note, though, that we do not observe a particular strong depreciation in our scenario analysis.

Aune et al. (2020), does also perform a sectoral analysis. Comparing theirs to ours, we observe discrepancies. They predict, among other things, that production in manufacturing will decline temporary, but then recover gradually over the forecast horizon in contrast with the 10 years decline observed in our forecast. Again, this might be due to the relatively small cut in fossil fuel production they are investigating. That being said, they predict that private services is the sector with the largest negative impact, which is on the contrary to our predictions where private services perform relatively well.

We do, however, run into some explanation problems in our sectoral analysis. In the manufacturing sector, the wage grows faster than the increase in productivity. It conducts us into a situation where increased salaries require overtime work. Such outcome does not seem to be realistic, given the historical trend to reduce hours worked per week. We face the same issue in the construction sector with increased hours work per employee. This issue is aggravated when considering private services. Here, average wage and labor productivity move in opposite directions. The increase in hours worked per employee must compensate for the fall in both employment share and productivity, making a large amount of overtime work even more unrealistic. The drop in productivity remains also a puzzle since we observe growing investment and an increase in the capital stock. Another issue that appears here is the fact that the employment share of the sectors does not add up to one in 2030. Even if we take into account the decline in aggregate employment to population ratio, as stated in Scenario 1, it still doesn't explain it. Therefore, we don't know exactly how resource reallocation is carried out in the whole economy.

The above objections make it difficult to rely on the results obtained from simulations at the sectoral level. Our analysis depends mainly on historical correlations. When using quarterly data, which are noisier compared to yearly data, one might get undesirable correlations that conduct to unrealistic forecasts. Moreover, even though we tried to seasonally adjust the wage and fossil fuel production series, it does not seem like the method succeeded in soaking up the seasonal variation. Seasonality in these variables might very well amplify the problem of noisy data. Furthermore, the fact that our VAR does not satisfy the stability condition might give rise to results that are overestimated. At last, when measuring the relative performance of sectors, it is crucial that the variables in each of the sector's baseline scenario is predicted to be the same. This is not the case. We do, for instance, observe in figure F,3 in appendix F, that production of petroleum is predicted to decline substantially more in private services sector in the baseline scenario, compared to other sectors. This might underestimate the impact reduced petroleum activity has on private services and might be the main driver for why private services performs relatively well.

7. Conclusions

7.1 Summary of results

When summarizing the results from our empirical analysis, it is important to do so in light of our research question:

What are the macroeconomic effects of measures aimed at reducing production of fossil fuels in Norway?

This question was investigated by specifying a VAR containing seven variables that were chosen based on Dutch disease theory. We established a purely data driven baseline scenario, in which petroleum production as well as oil price, where predicted to remain close to fixed towards 2030. In section 5, we started out by constructing two scenarios where we implemented cuts in petroleum production based on Norwegian climate objectives and latest findings by IPCC. Our analysis suggests that the macroeconomic effects arising from reduced petroleum activity are large, as it causes GDP to stagnate and employment to decline towards 2030. Moreover, it engenders deflation in the Norwegian economy and pushes Norwegian labor productivity back to early 2000's level but does not seem to affect the REER towards 2030.

In Scenario 3, we extended Scenario 2 by investigating how the oil price is predicted to affect the Norwegian economy on the road to 2030. Our predictions from this scenario imply that an increasing oil price has unfavorable effects on the Norwegian economy. As argued in section 5.4, our predictions are to a large extent in line with Dutch disease studies conducted for the Norwegian economy and supports the view of strong LBD effects in the petroleum sector, which spill over to other branches of the economy and generates positive growth effects. In section 6, we aimed at understanding how other branches of the economy are related to the petroleum sector. By investigating predictions for the main sectors of the economy, we found that all branches tend to contract followed by reducing petroleum activity, but stressed the shortcomings of our framework when investigating less aggregated data at higher frequency.

7.2 Implications for the Norwegian economy

Our analysis provides a benchmark for policymakers, as it utilizes historical relationships among real macroeconomic variables, while neglecting the effect of policy variables. In that sense, the empirical analysis in this thesis provides predictions for what we can expect if relationships among variables remains as in 2019 and in the absence of political measures. Predictions of low growth and falling productivity the next decade indicates the importance of adaptability among industries in the domestic economy. Industries supplying goods and services to the petroleum sector needs to develop new production technologies and aim for alternative markets in order to ensure a source of stable income. This will require active policies that facilitates a smooth transmission for these industries. Furthermore, in order to compensate for the loss of learning and the spillovers this brings, investments directed towards research and development should increase drastically the next decade.

Our analysis predicts the employment share of the economy to decline towards 2030. A shortcoming of our framework is that we are not able to identify whether these effects results into lower working force or higher unemployment. We do, however, believe that our predictions highlight the importance of labor market policies. We know that workers deployed on the continental shelf are living all across Norway. When these workers are going to find work on land, they will most likely be forced to move, as onshore production is location specific. This is problematic for a number of reasons and could be causing long-term unemployment and therefore reduce future Norwegian production capabilities. Moreover, workers transitioning from working offshore would require reschooling, which is not easily done in the short-term, and that could draw in the direction of a temporary increase in unemployment as well.

An important factor for both productivity and employment, which we do not take into account, is how capital and personnel in today's petroleum sectors is being utilized the next decade. Norway can reach climate objectives by applying other instruments than reducing production itself. One possibility could be to electrify production of petroleum, which will maintain activity on the continental shelf and most likely generate more know-how, as well as ensuring stable employment. Furthermore, as of now, it might seem like renewable energy in the future will be brought about by the same companies extracting petroleum today, as the continental shelf of Norway has proved itself to be suitable for renewable production technologies, such as floating wind turbines and carbon capture. Under such circumstances, could growth and employment development in the economy differ substantially from our predictions.

We do not take a stand on how Norway reduces its production level of fossil fuels. It is reasonable to assume that this could be done through incentive altering instruments like taxes. Governmental revenues arising from this could be used to dampen the effects predicted in our analysis, by investing in research and development and ensuring a strong labor market. However, tax income and potential income from renewable energy will most likely never make up for the revenue loss resulting from reduced petroleum exports towards 2030. Hence, macroeconomic policy will be crucial to dampen domestic upheavals and to ensure Norway's ability to compete in international markets. Our analysis has shown that the domestic price level suffers substantially, and that the REER does not seem to respond to petroleum production itself. This calls for actions by the central bank, which in according to our predictions, should be to lower the policy rate in order to stimulate domestic demand and to depreciate the REER, so that other industries can prosper as petroleum exports are being reduced towards 2030.

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9. Appendices

Appendix A: Complete list of industries included in sectors.

<u>Manufacturing</u>	- Food products, beverages, and tobacco. - Textiles, wearing apparel, leather. - Manufacture of wood and wood product, except furniture. - Manufacture of paper and paper product. - Printing and reproduction of recorded media. - Refined petroleum, chemical and pharmaceutical products. - Manufacture of basic chemicals. - Rubber, plastic and mineral products. - Manufacture of machinery and other equipment. - Buildings of ships and other transport equipment. - Manufacture of furniture and other manufacturing. - Repair and installation of machinery and equipment.
<u>Private Services</u>	- Wholesale and retail trade, repair of motor vehicles. - Transport via pipelines. - Ocean transport. - Transport activities, excluding ocean transport. - Postal and courier activities. - Accommodation and food service activities. - Information and communication - Financial and insurance activities. - Real estate activities. - Housing services, owner-occupied house. - Professional, scientific and technical activities. - Administrative and support services activities. - Education - Health and social care - Arts, entertainment and other activities.
<u>Public sector</u>	- Central government - Civilian central government - Defense - Local government
<u>Natural resources</u>	- Agriculture and forestry - Fishing and aquaculture - Mining and quarrying
<u>Construction</u>	- Construction

Appendix B: Extended sample model.

We decided to run again scenario 1 with one additional observation from 2020 to check the robustness of the previous results. The increase in fossil fuels production is more significant and reaches a level of 249 million Sm3 oil equivalent, making up an increase of 18.5 % over 10 years. The oil price experiences a small decline from 235 to 228. The production in the baseline scenario is twice higher than in the conditional forecast while price differs only by 3 percent in 2030.

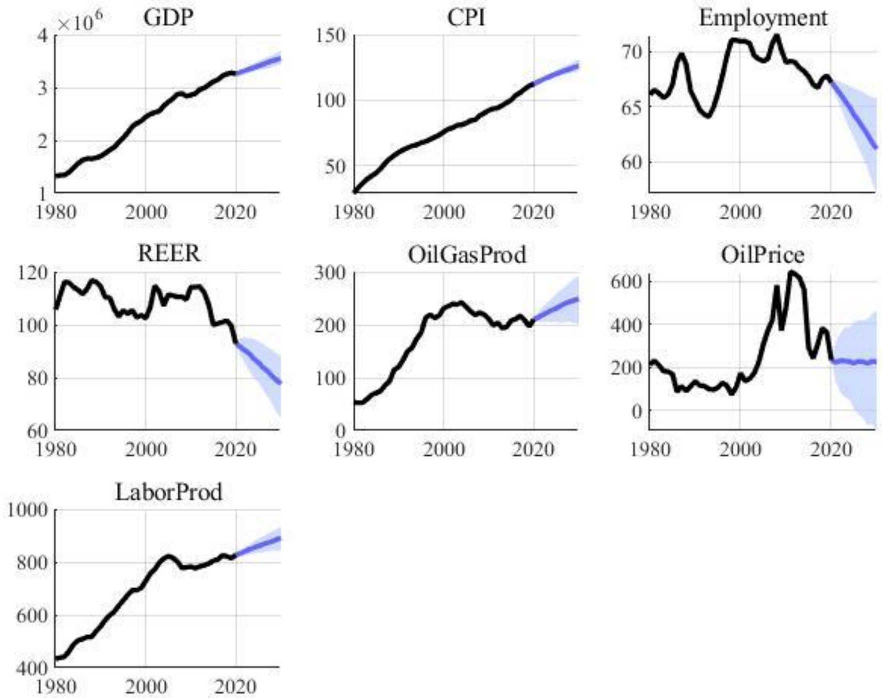

Figure B, 1. *Unconditional forecast. The median forecast for each variable is given as the dark blue line, which starts in 2021 and ends in 2030. The shaded light blue area represents corresponding 68% probability bands.*

The GDP starts out increasing until mid- 2020 but then stagnates and decreases over the last three years of forecast. Hence the 10 years growth rate only makes up 2.8 percent. The baseline scenario on the other hand predicts a constant yearly growth rate that amounts to 9.1% over ten years. Reduced growth seems to impact the CPI and causes it to decline until 2025 before gradually picking up again. It ends up at a level of 108.4 in 2030 which implies and average deflation rate of 0.38 percent over ten years. The baseline scenario in contrast predicts an average yearly inflation of 1.24 percent.

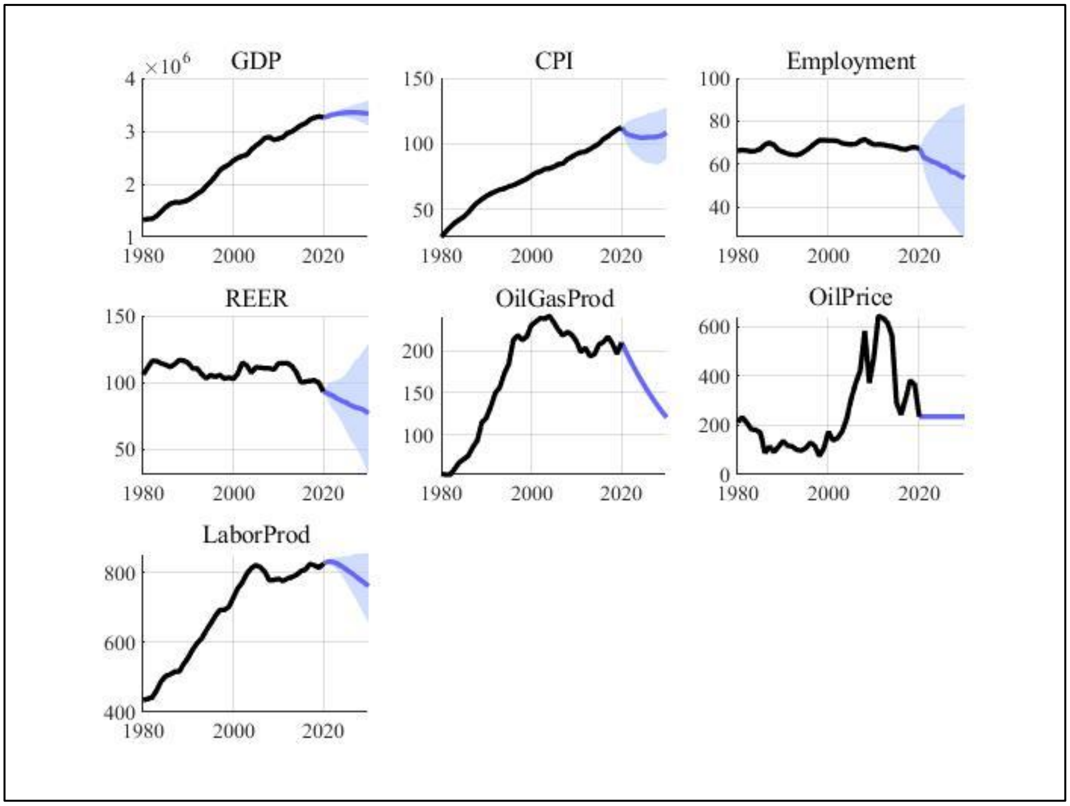

Figure B, 2. *Conditional Forecast.* The median forecast for each variable is given as the dark blue line, which starts in 2021 and ends in 2030. The shaded light blue area represents corresponding 68% probability bands

Employment drops from 67.2 in 2020 to around 53.5 in 2030 while the path in the baseline scenario ends at higher level of 61.2. The cut in fossil fuels export brings an additional decrease in employment of 7.7 percentage points. The REER depreciates almost by the same amount in both the baseline and conditional forecast, approximately 17 percent. Productivity experiences also a substantial decline and falls from 826 to 761 NOK in 2030 while it is expected to reach 892 NOK in the baseline scenario.

Appendix C: Stable Model.

The estimated VAR models used in our main analysis did not satisfy the stability condition. Therefore, we decided to run a model with a stable VAR. To that aim we, had to pick up a few different variables in our VAR. We substituted aggregate GDP by GDP per capita and production of fossil fuels by the share of petroleum exports to nominal GDP. Figure C,1 and C,2 provides the baseline scenario and conditional forecast, respectively. The difference plot is provided in C,3.

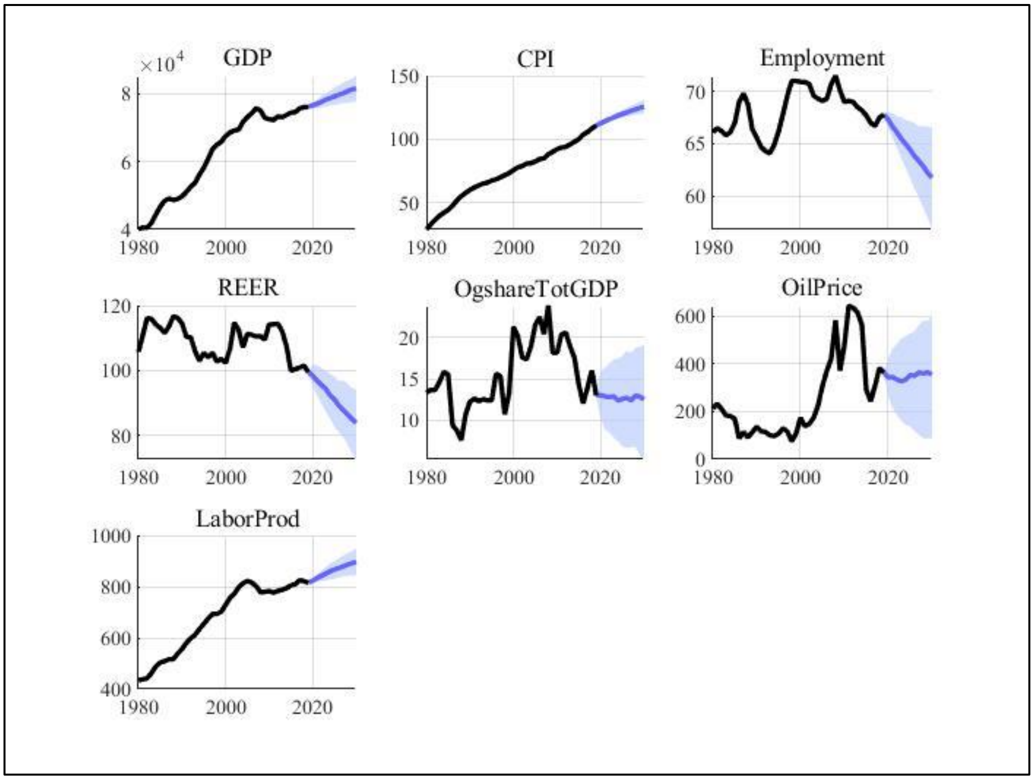

Figure C, 1. *Unconditional forecast. The median forecast for each variable is given as the dark blue line, which starts in 2020 and ends in 2030. The shaded light blue area represents corresponding 68% probability bands.*

From the difference plot we observe that GDP per capita is three percent lower in the conditional forecast, compared to the baseline scenario in 2030. CPI is predicted to follow similar path in both forecasts. Employment in 2030, on the other hand, is eight percent lower in the conditional forecast than employment predicted in the baseline scenario. The REER depreciates in the conditional forecast and makes up 92 percent of the REER predicted in the baseline scenario in 2030. Labor productivity is three percent lower in the conditional forecast than predicited labor productivity in baseline scenario.

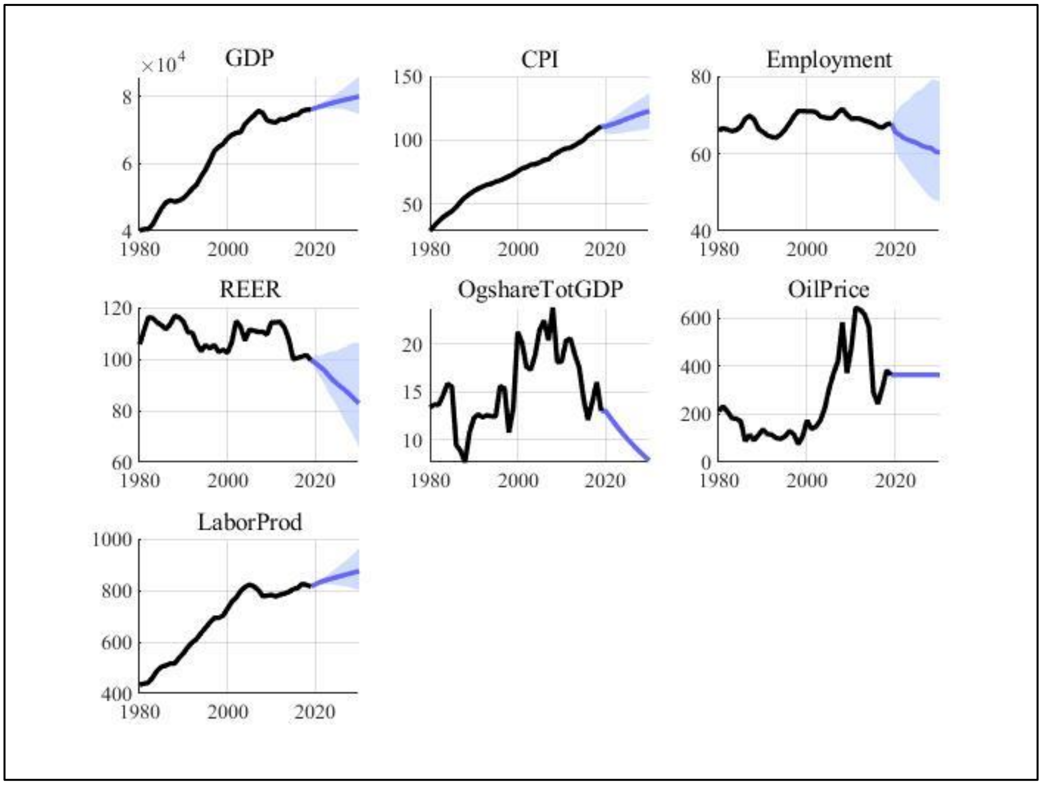

Figure C, 2. *Conditional Forecast.* The median forecast for each variable is given as the dark blue line, which starts in 2020 and ends in 2030. The shaded light blue area represents corresponding 68% probability bands

It is important to notice, however, that petroleum production level and petroleum as share of GDP differ in several points. The latter is much more volatile because of fluctuations in prices and moves along a stochastic path essentially under the effect of price shocks. While production follows a more deterministic path mainly under the effect of activity shocks. We know that activity shocks are the main drivers of variables like GDP growth and productivity in a resource-based economy like Norway. As a result, the fall in share to GDP does not show the isolated effect of a cut in production and therefore it does not lead us to the same outcomes observed previously. But it confirms them in a different way.

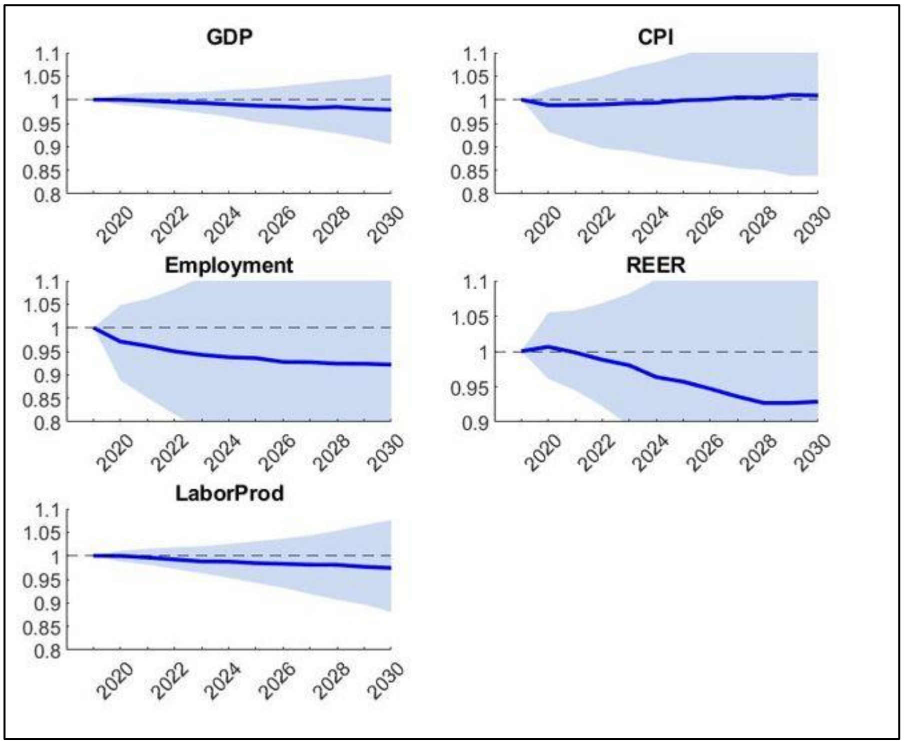

Figure C, 3. *Difference plot, 2019-2030. The median share of* Conditional forecast-to-baseline scenario at each horizon is given by the dark blue line. The light blue shaded area represents the corresponding 68 % interquartile.

Appendix D: Unconditional forecasts, Scenario 2 and 3.

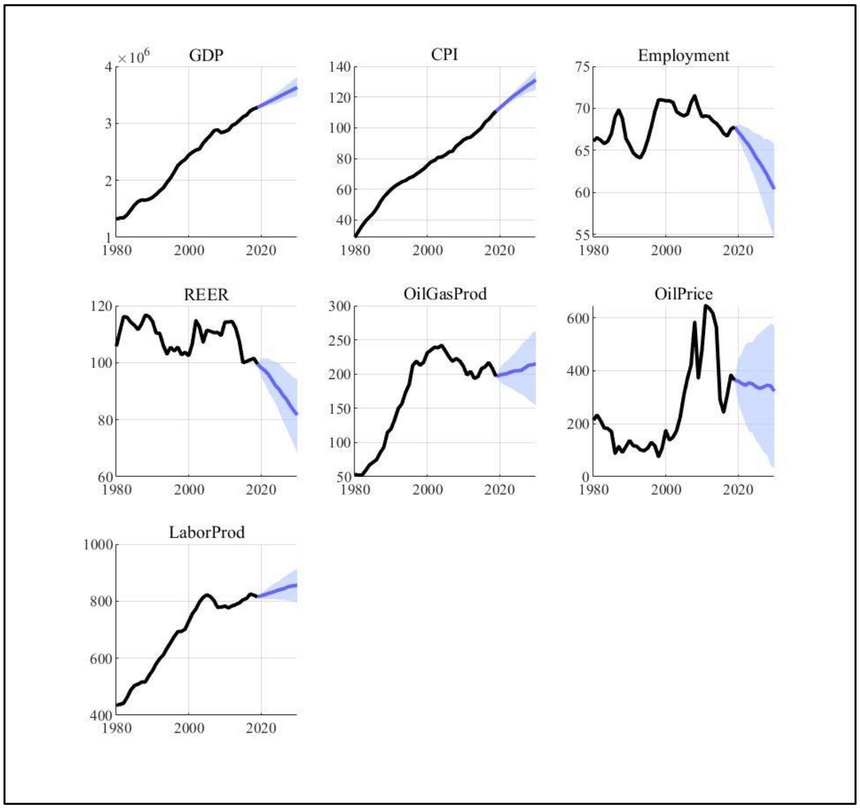

Figure D, 1. *Unconditional forecast (Scenario 2). The median forecast for each variable is given as the dark blue line, which starts in 2020 and ends in 2030. The shaded light blue area represents corresponding 68% probability bands.*

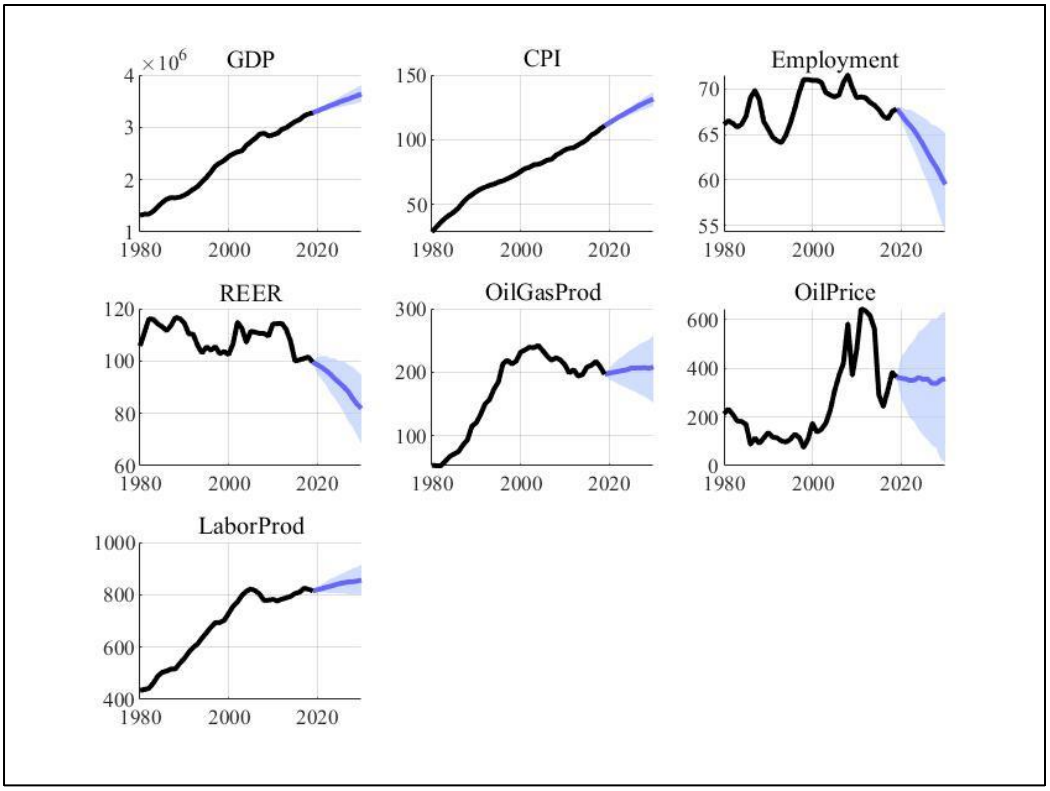

Figure D, 2. *Unconditional forecast (Scenario 3). The median forecast for each variable is given as the dark blue line, which starts in 2020 and ends in 2030. The shaded light blue area represents corresponding 68% probability bands.*

Appendix E: Sectoral Analysis. Public and Natural resources sector.

E.1 Public Sector

The baseline scenario and conditional forecast is displayed in figure E,1 and E,2, respectively. E,3 visualizes the conditional forecast as a share of the baseline scenario.

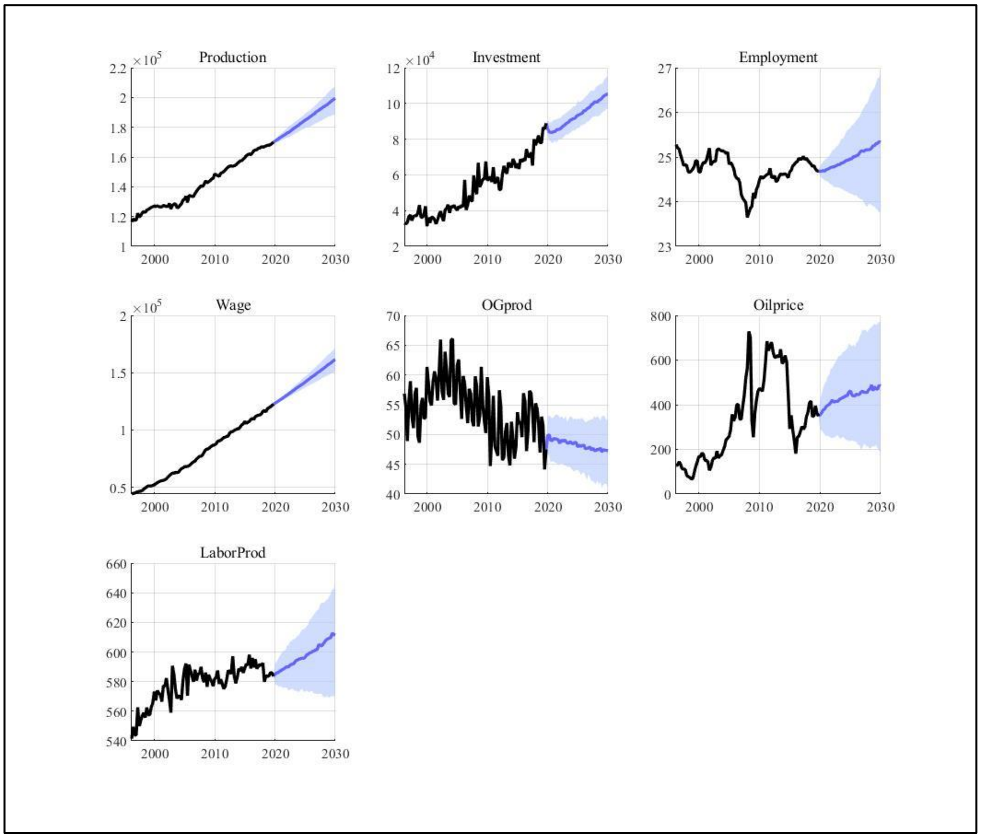

Figure E, 1. *Unconditional.* The median forecast for each variable is given as the dark blue line, which starts in 2020q1 and ends in 2030q1. The shaded light blue area represents corresponding 68% probability bands

Production in the baseline scenario is predicted to continue upwards along its historical trend, making up an increase of 16,9 percent from 2020 to 2030. Positive growth rates are also observed in the conditional forecast over the same period, though smaller, making up an increase of 9,5 percent. Figure E,3 shows that the production is six percent lower in the conditional forecast compared to the baseline scenario in 2030. Similar pattern is being observed for Investment. It increase by 18,8 and 17,9 percent in the baseline scenario and the conditional forecast, respectively. As seen in figure E,3, the difference in 2030 is negligible.

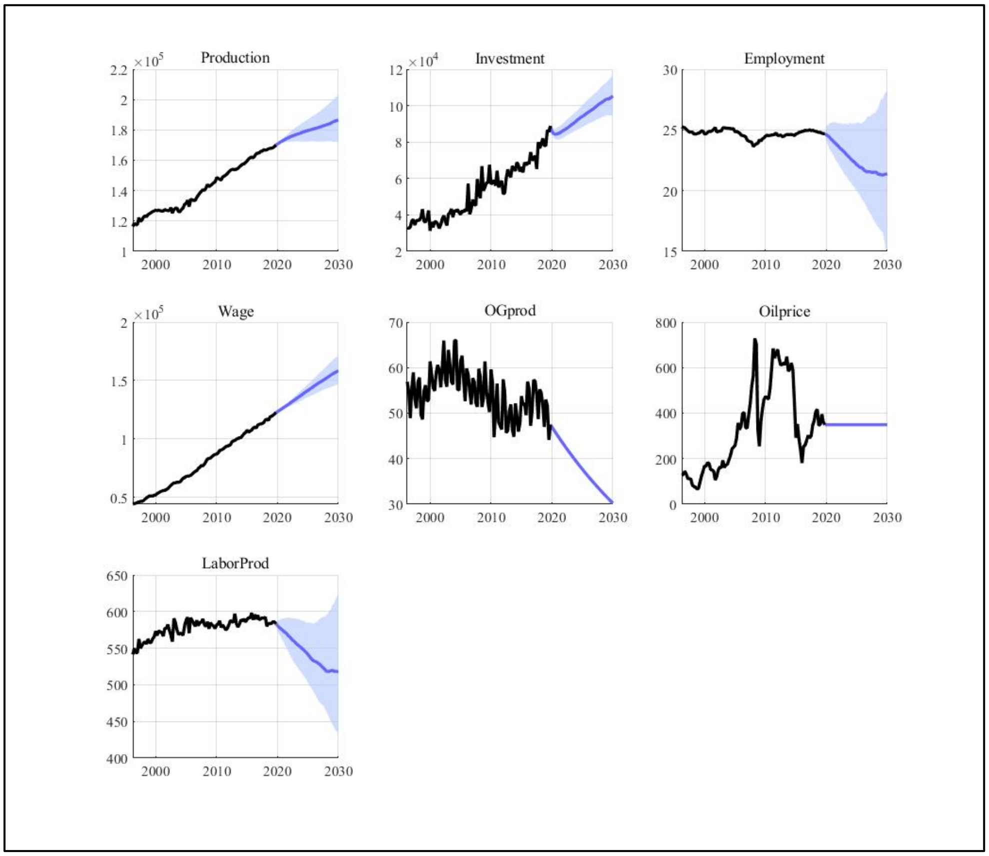

Figure E, 2. *Conditional*. The median forecast for each variable is given as the dark blue line, which starts in 2020q1 and ends in 2030q1. The shaded light blue area represents corresponding 68% probability bands.

The employment share is being reduced by 3,4 percentage points in the conditional forecast, while it increases by 0,6 percentage points in the baseline scenario from 2020 to 2030. In 2030, we see that the employment share predicted in the conditional forecast is 14,8 percent lower than the employment share predicted in the baseline scenario. The wage level increases over the horizon in both forecasts. It increases by 31,5 percent in the baseline scenario, while it increases by 27,9 percent in the conditional forecast. In figure E,3 we see that the wage level in the conditional forecast makes up as much as 98 percent of the wage level predicted in the baseline scenario.

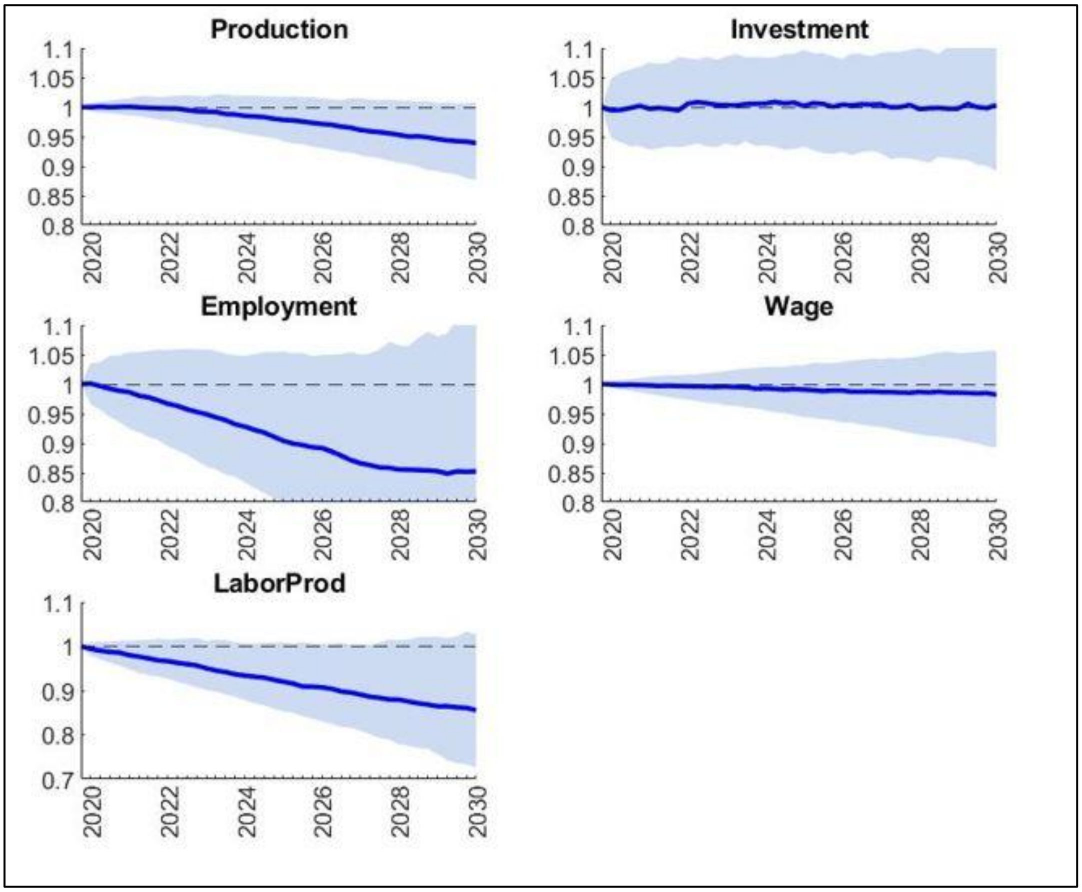

Figure E, 3*. Difference plot, 2019q4-2030q1. The median share of* Conditional forecast-to-baseline scenario at each horizon is given by the dark blue line. The light blue shaded area represents the corresponding 68 % interquartile.

Labor productivity is the variable that seems to be the most affected followed by reduced fossil fuel production. It is predicted to increase by four percent in the baseline scenario, while it is being reduced by 10 percent in the conditional forecast by 2030. Hence, productivity in the conditional forecast is 14,4 percent lower than productivity predicted in the baseline scenario.

But still it is reasonable to conclude that the public sector is rather well shielded against the effect of a negative oil shock and will suffer the least.
Fewer people at work while production and investment are increasing over the forecast period. The growth in those variables was accompanied by an increase in the number of people at work and consequently hours worked (in baseline). At the same time we see that production is slightly lower that the baseline, so we can state with some confidence that total hours worked has gone up compared to baseline again. Therefore, to get more hours worked while having fewer people at work who are less

productive, it requires an increase in hours worked per employee. It also drives the increase of the average wage in the sector. Wage level is almost the same as in the baseline while we have increased total hours worked. Again, it means a drop in average hourly wage compared to baseline outcome in 2030

E.2 Natural Resources sector

The baseline scenario and the conditional forecast is displayed in figure E,4 and E,5, respectively. Figure E,6 provides the conditional forecast as a share of the baseline scenario. From figure E,4 we see that production in the baseline scenario is predicted to increase by 19, 6 percent over the forecast horizon. The conditional forecast, on the other hand, predicts it to decline by 4,5 percent over the same period.

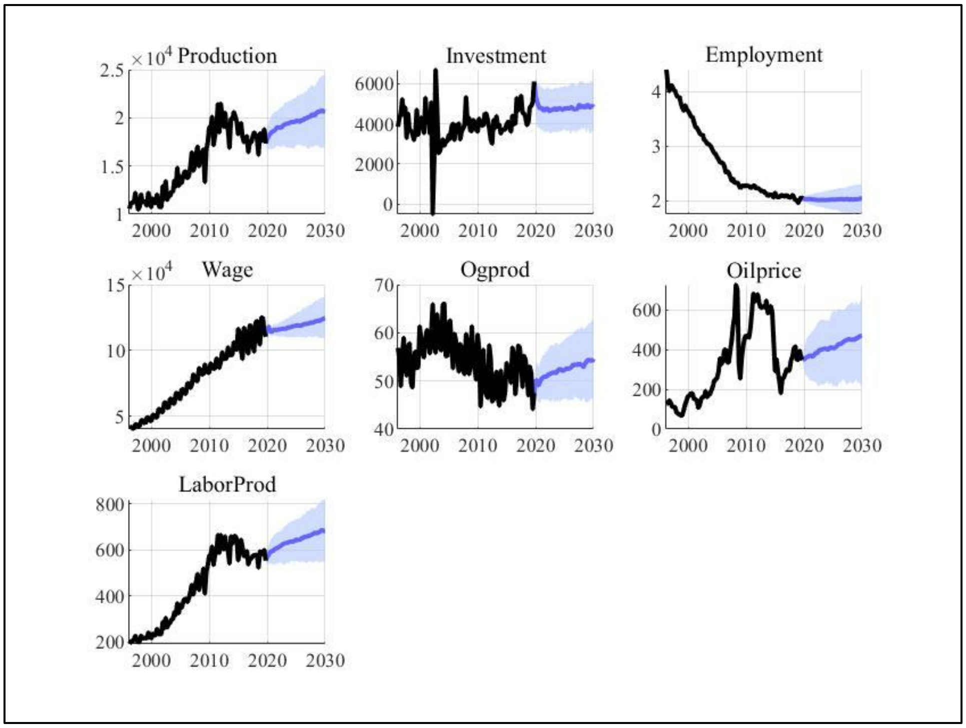

Figure E, 4. *Unconditional.* The median forecast for each variable is given as the dark blue line, which starts in 2020q1 and ends in 2030q1. The shaded light blue area represents corresponding 68% probability bands.

Figure E,6 tells us that these predictions result in an investment level in the conditional forecast that is 18,9 percent lower than the investment level in the baseline scenario in 2030. Investment is predicted to decline by 22,1 and 40,4 percent in the baseline scenario and the conditional forecast, respectively. In 2030, we see that the amount of investment is 23,4 percent lower in the conditional forecast than in the baseline scenario.

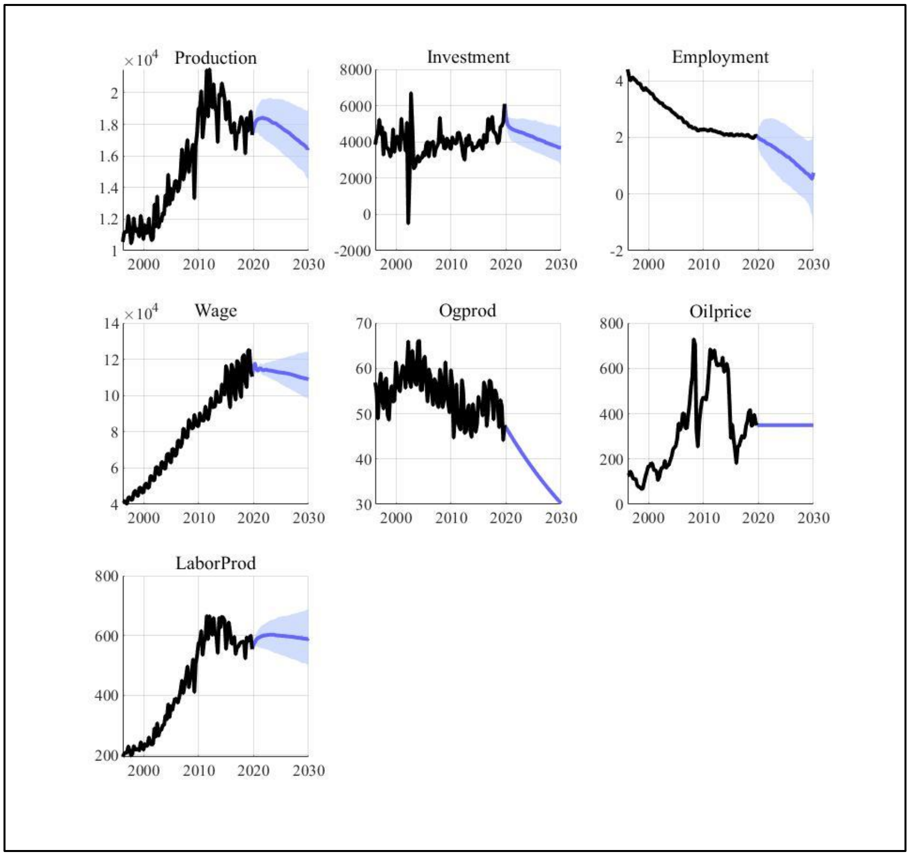

Figure E, 5. *Conditional.* The median forecast for each variable is given as the dark blue line, which starts in 2020q1 and ends in 2030q1. The shaded light blue area represents corresponding 68% probability bands.

The employment share has been stagnating around two percent since 2010 and is expected to stay around this value in the baseline scenario. However, it drops to a historical low level of 0.66 percent in the conditional forecast, dropping by 1,3 percentage points. As seen in E,6, this decrease constitutes a large share of the employment share in this sector, so employment in the conditional forecast is 65,1 percent lower than employment predicted in the baseline scenario. Therefore, the cut in the fossil fuel sector might be a turning point for the employment share in the natural resources sector. The wage level of the sector is predicted to decrease slightly in the conditional forecast, making up a reduction of two percent towards 2030, while it is predicted to increase by 13 percent in the baseline scenario over the same timeline. As observed in figure E,6, the wage level predicted in the conditional forecast is 11 percent lower in the conditional forecast compared to the baseline scenario. Despite from decreasing wages, is labor productivity predicted to keep increasing in the conditional forecast, though, at a slower pace than in the baseline scenario. In 2030, we see that labor productivity in the conditional forecast is 13,6 percent lower than in the baseline scenario.

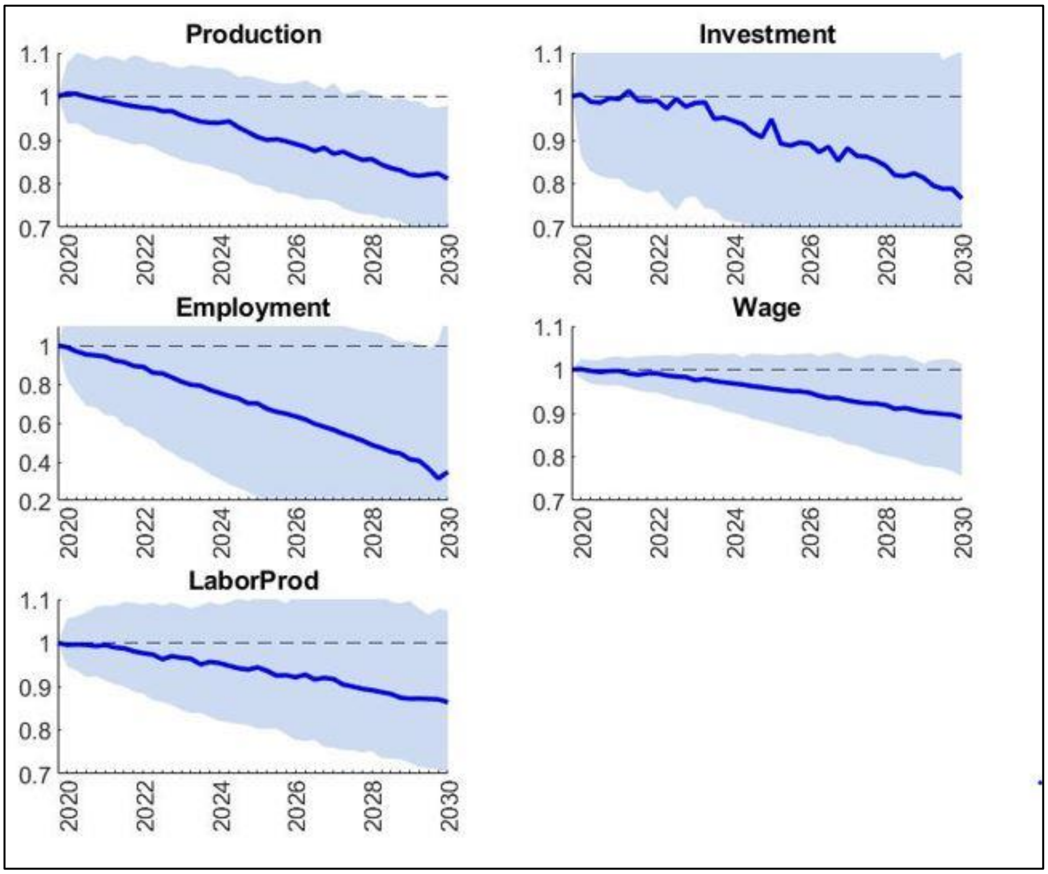

Figure E, 6. *Difference plot, 2019q4-2030q1. The median share of* Conditional forecast-to-baseline scenario at each horizon is given by the dark blue line. The light blue shaded area represents the corresponding 68 % interquartile.

In the case of the manufacturing sector, the trend was already falling and has only been aggravated as a consequence of the cut in the fossil fuel sector. Also, as opposed to the manufacturing sector, where the wage level continues increasing, There are again fewer people at work, less capital and therefore production level will be lower. Both productivity and wage are downward sloping and that's because of a decline in the marginal productivity of labor. However, salary takers are a small share of employment in this sector

Appendix F: Unconditional forecasts, sectoral Analysis.

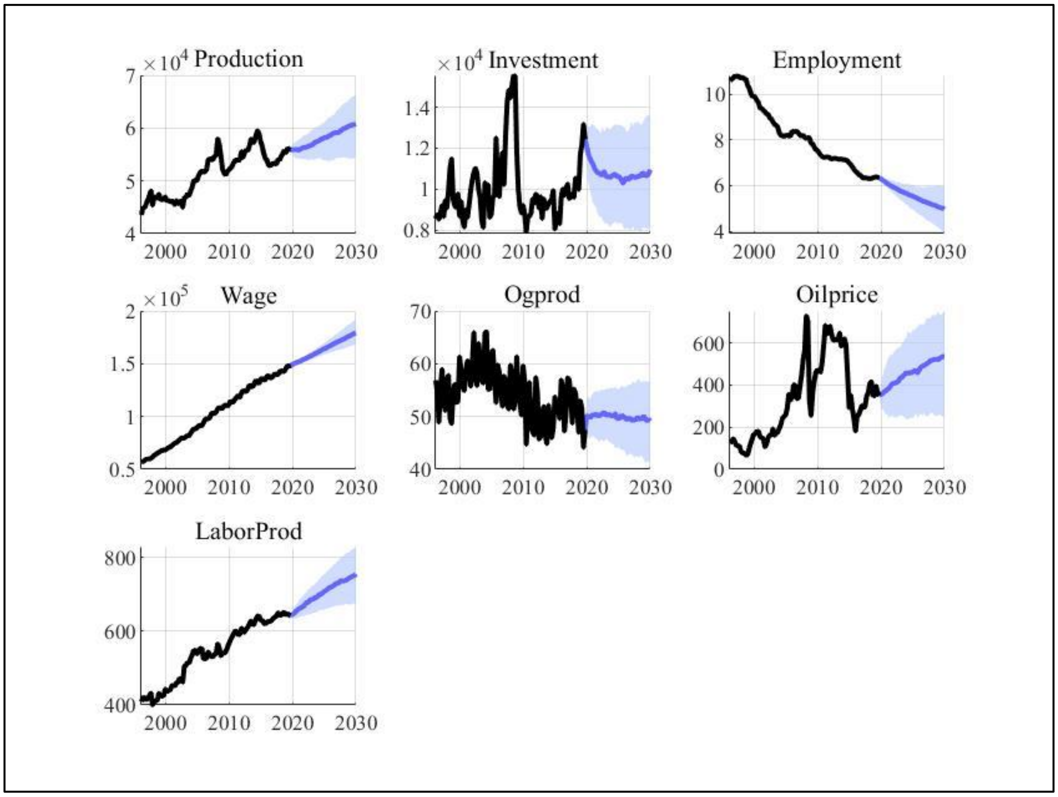

Figure F, 1. Unconditional Forecast (Manufacturing). *The median forecast for each variable is given as the dark blue line, which starts in 2020q1 and ends in 2030q1. The shaded light blue area represents corresponding 68% probability bands.*

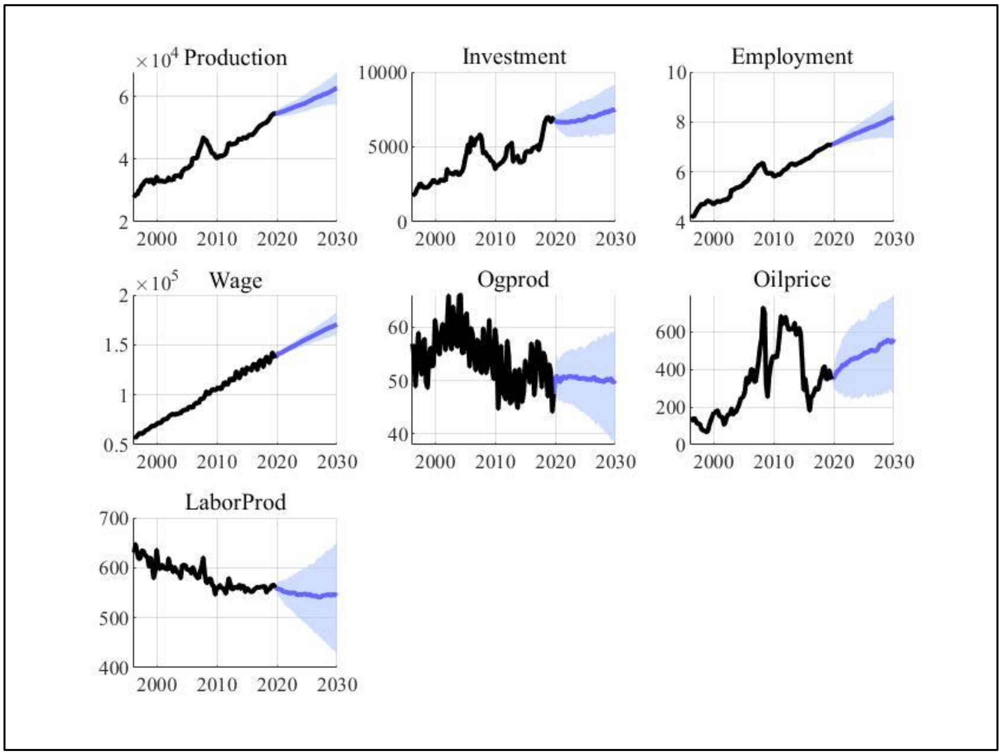

Figure F, 2. *Unconditional Forecast (Construction).* The median forecast for each variable is given as the dark blue line, which starts in 2020q1 and ends in 2030q1. The shaded light blue area represents corresponding 68% probability bands.

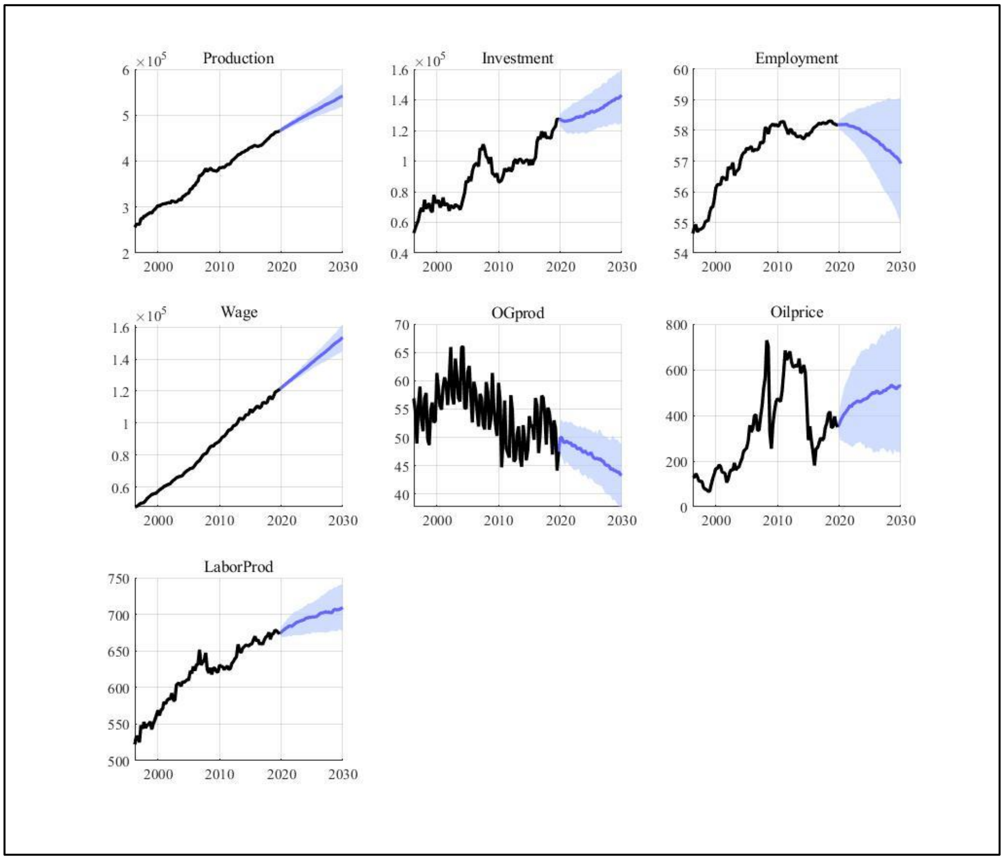

Figure F, 3. *Unconditional Forecast (Private Services).* The median forecast for each variable is given as the dark blue line, which starts in 2020q1 and ends in 2030q1. The shaded light blue area represents corresponding 68% probability bands.