IMPACT ON GROWTH OF DISINVESTMENT FROM FOSSIL FUELS

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Abstract

This paper presents the impact on growth of a massive disinvestment in the fossil fuel sector based on macroeconomic tools such as the Green Solow Model for the long term and IS/LM and WS/PS for the short and medium term. In the current theme of climate change, this work wishes to bring an economic point of view to environmental and social problems, and in particular to derive the impact of the disinvestment movement of fossil energies. It is found that, under certain hypotheses, the effect of this movement is beneficial in the long term on growth and despite some questioning about the possibility of recession in the short and medium term, the analysis of Saudi Arabia and the Dutch Disease gives interesting results for the consequences of a decrease in the use of fossil fuels and advice on diversification for countries dependent on fossil fuels.

1 Introduction

Before mathematically and economically analyzing the problem of climate change and a possible solution that is the disinvestment from fossil fuels, it is important to contextualize the situation. During the first decade of the 21^{st} century, politicians have begun to recognize the importance of limiting carbon dioxide emissions, but some pressure was added when the report "Unburnable Carbon" was published, explaining that consuming all fossil fuel reserves would emit five times more CO_2 than what is needed to limit global warming to 2 °C by 2050[1]. From that moment on, many movements were launched around the world, most notably the "Fossil Fuel Divestment Movement"[2] which emerged in the early 2010's on university campuses in the United States, driven by their students to free themselves from any investment in fossil fuels. Since then, counting until December 2019, a total of 1156 institutions and more than 58'000 individuals representing, in all, nearly 12'000 billion dollars (USD) have changed course for their investments[3].

Divestment is an interesting solution from the point of view of many investors to protect themselves against the speculative bubble in the carbon markets,[4] particularly through two effects. The first, indirectly, through a social movement that is pushing legislation to change the rules of the game in terms of fossil fuels. The second, more directly, simply by reducing the share of investment in fossil fuels. The aim is to have a portfolio that is less exposed to more restrictive climate change policies that can heavily affect the economics of non-renewable energy.

Some countries and economies rely heavily on the export of fossil fuels and a decrease in external demand for oil, natural gas or coal could have a real impact on their growth and on the standard of living of their inhabitants. Despite a certain ease of adaptation in the medium term, institutions in some countries do not have the capacity to respond to blitzkrieg climate policies. These policies have the capacity to heavily affect exports, and thus the overall economy of some fossil fuel producing countries and their trading partners.

After a short introduction on fossil energies, its producers and consumers, the article will be introduced by the example of the Norwegian pension fund and the reasons for its disinvestment. In the second chapter, long-term growth will be analysed using the environmental Solow model to understand whether the effects of disinvestment from fossil fuels are negative for growth. In the third and last chapter, the case of Saudi Arabia, a major oil producer, and the impact that disinvestment in oil products would have on its local economy will be highlighted. The three parts of the article allow the reader to understand whether disinvestment in fossil fuels is really bad for economic growth.

1.1 Fossil fuels

Fossil fuels include mainly coal, oil (and other oil-based products) and natural gas. The production as well as the consumption of fossil fuels began more than 6000 years ago in China when humans began to make engravings with coal [5]. Large-scale combustion, on the other hand, began during the period of

[1]Carbon Tracker Initiative - Unburnable Carbon - `https://www.banktrack.org/download/unburnable\_carbon/unburnablecarbonfullrev2.pdf`

[2]The Guardian - Fossil Fuel Divestment: A brief history - `https://www.theguardian.com/environment/2014/oct/08/fossil-fuel-divestment-a-brief-history`

[3]GoFossilFree - `https://gofossilfree.org/divestment/commitments`

[4]Carbon Tracker Initiative - Are the world's financial markets carrying a carbon bubble? - `https://www.banktrack.org/download/unburnable\_carbon/unburnablecarbonfullrev2.pdf`

[5]Our World in Data - Fossil Fuels Consumption - `https://ourworldindata.org/fossil-fuels\#global-fossil-fuel-consumption`

the industrial revolution. After more than 150 years of using fossil fuels, we see the harmful effects they have on our environment, but they have not brought only bad things.

The explosion in the use of fossil fuels is an unprecedented event in the history of mankind that has given industry, transport and heating solutions unprecedented access to energy. In no century had the population of humanity doubled, whereas in the 20th century it almost quadrupled. This energy revolution was also felt in the world's GDP, which doubled more than four times during the same century. The main countries producing fossil fuels are Russia for natural gas, Saudi Arabia for oil and China for coal. More precisely, the graphs 1, 2 and 3 show the production of the three main fossil fuels and the evolution of this production, by country, over time [6]. It is quite clear that some countries are the major players in the production of fossil fuels, such as Russia for natural gas, China for coal and, for oil, Saudi Arabia and the United States. These countries are likely to be affected by a decrease in the use of these different resources. The case of Saudi Arabia will be studied later in this work to show the real effect that disinvestment from fossil fuels could have in the short and medium term.

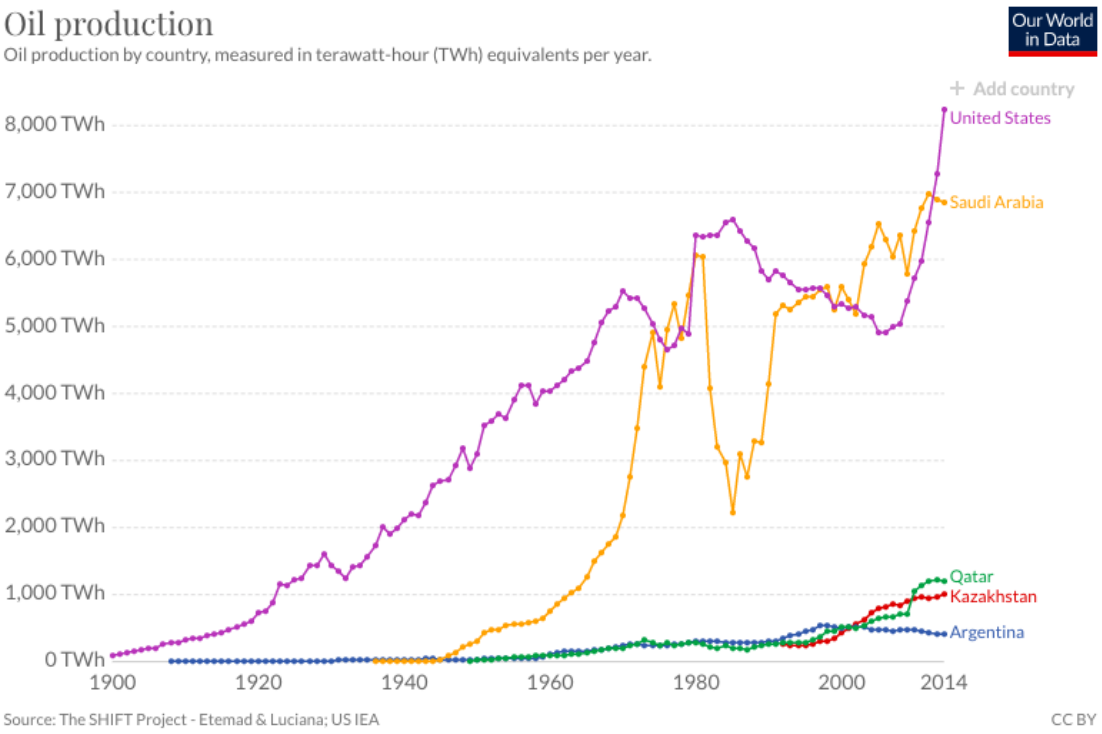


Figure 1: Oil production by country

[6] Our World in Data - Fossil Fuels - `https://ourworldindata.org/fossil-fuels`

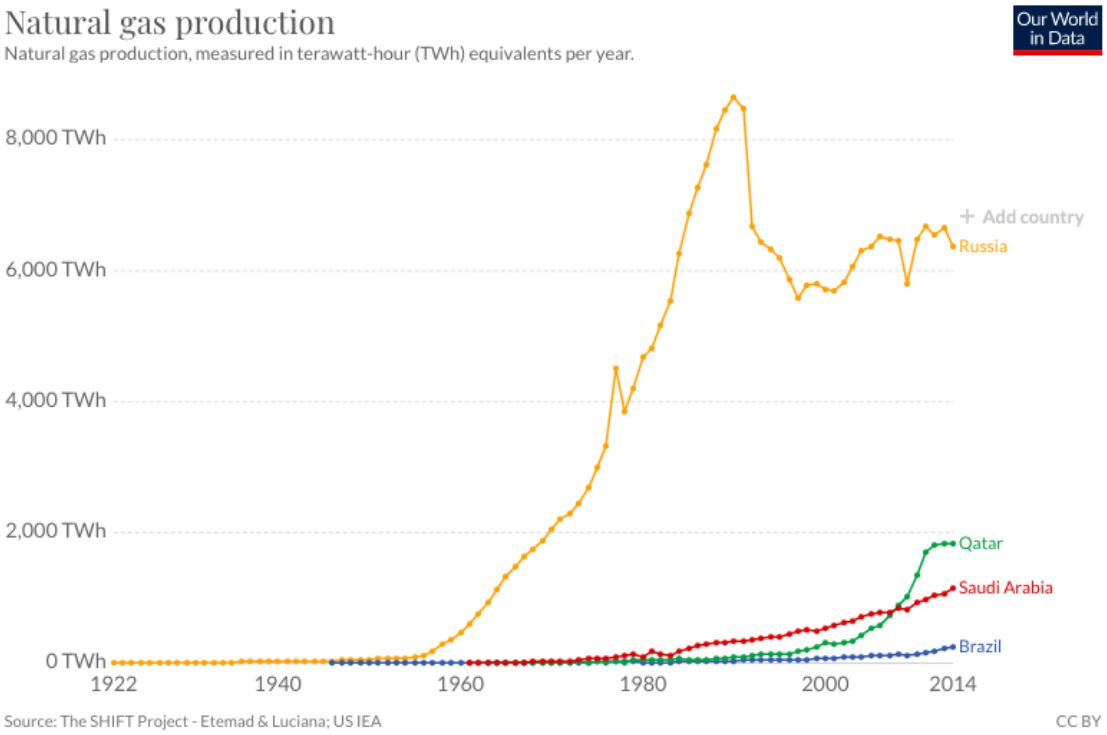


Figure 2: Gas production by country

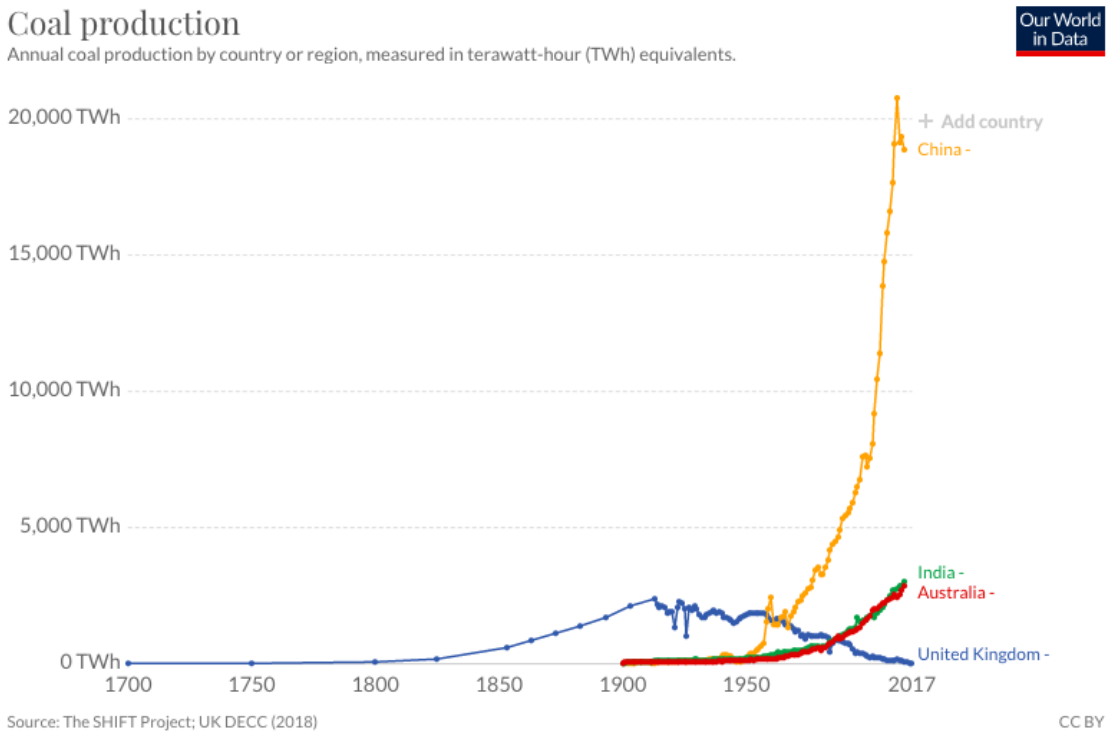


Figure 3: Coal production by country

The countries that consume this type of energy are often the producers of it. For example, China

has the highest per capita consumption of coal with nearly 16 MWh in 2015[7]. Saudi Arabia consumes a lot of oil but also natural gas with 34.64 MWh per capita in 2015. From the graphs 4, 5 and 6 we clearly notice that there are also inequalities between countries in terms of global warming. Those responsible are the producers as well as the consumers, which are generally the same countries, while some continents pose a lesser problem.

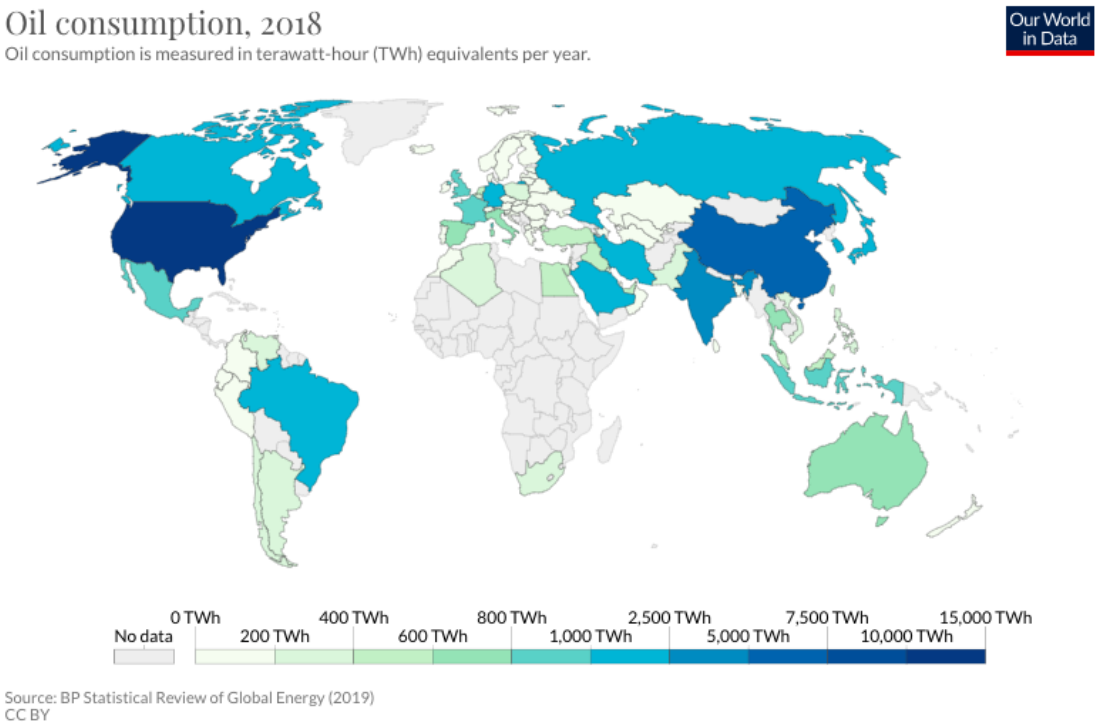


Figure 4: Oil consumption

[7]Our World In Data - Fossil Fuels - `https://ourworldindata.org/fossil-fuels\#coal`

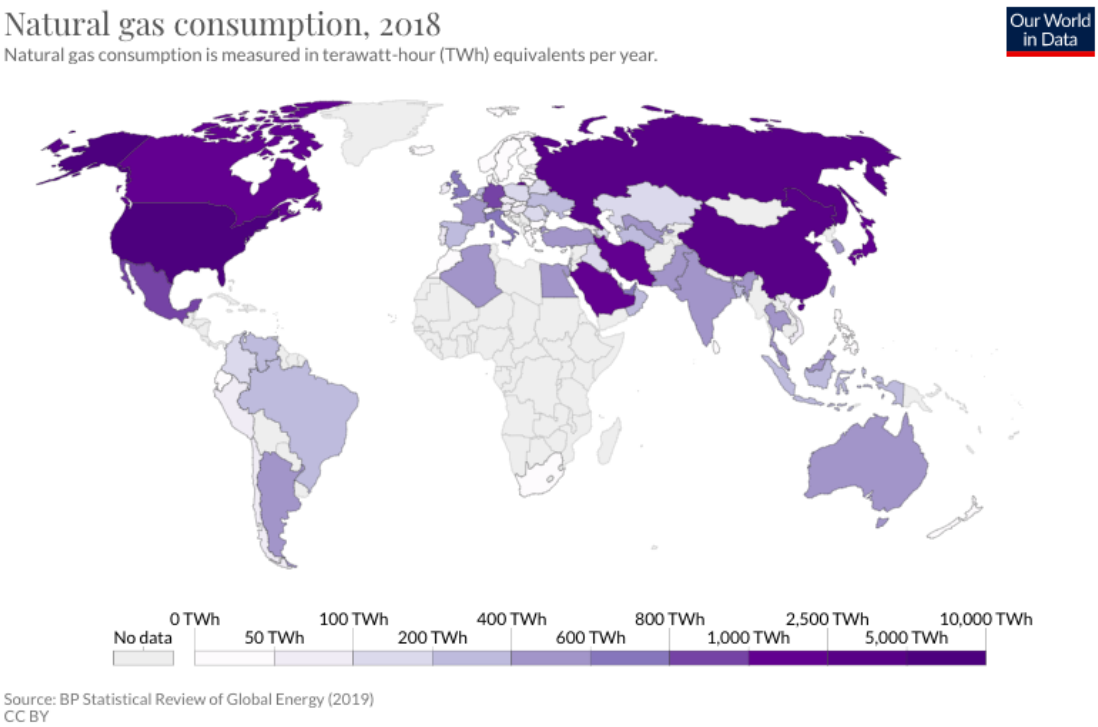


Figure 5: Natural gas consumption

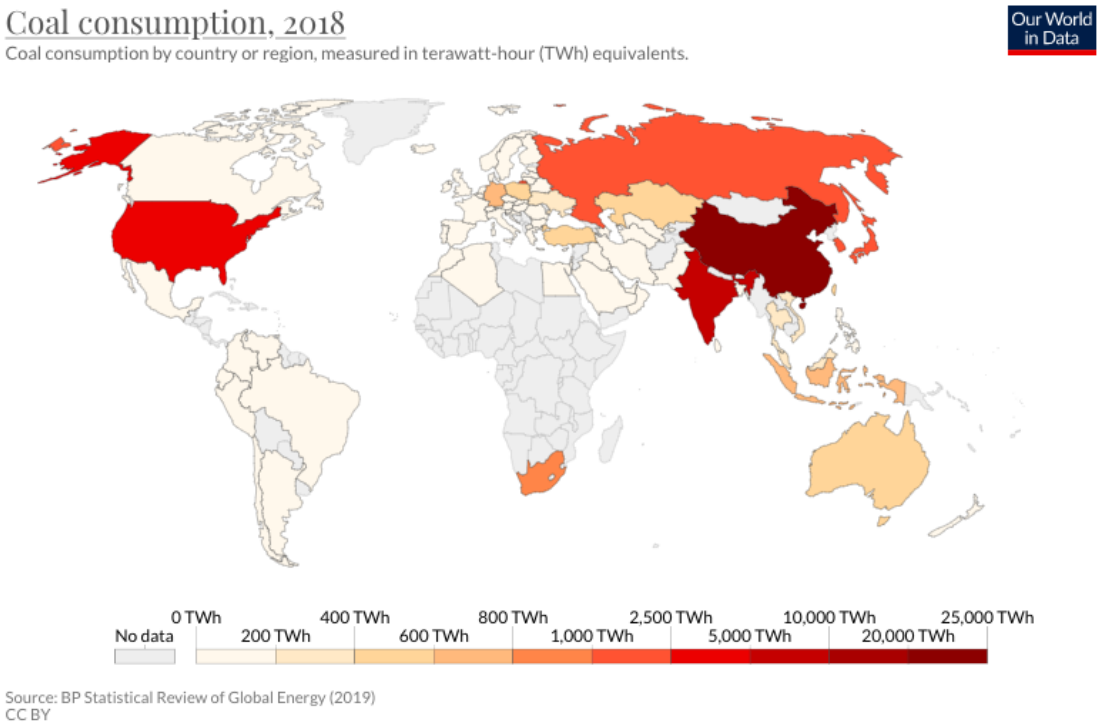


Figure 6: Coal consumption

Despite the economic benefits that these different energies have brought to society over the last century, the consequences are far-reaching. Indeed, according to numerous recent scientific reports, the

effect of their use is causing significant and extremely rapid climate change. The dangers of such climate change are of course social, with countries being submerged, natural disasters becoming more frequent and millions of refugees forced to flee drought. These problems are well known, but the economic dangers a little less so. From a financial point of view, such social upheavals, great uncertainty as well as a growing fear among the population could push investors to protect their assets by withdrawing them from the market and, as a priority, from the fields of fossil energies as will be presented in the rest of this document. From a macroeconomic point of view, in the long term many could imagine that, since growth has been largely based on natural resources in the past, such disinvestment would be a disaster, all the more so for countries dependent on these resources. These assertions will be challenged in the remainder of this report.

1.2 The Norwegian pension fund and its divestment

According to the March 2019 article in The Guardian [8], it is explained that the largest sovereign fund has begun its divestment from fossil fuels. The Norwegian sovereign fund or GPFG (Government Pension Fund-Global) was established in 1990 to manage foreign exchange reserve surpluses from the Norwegian government's oil exports and is managed by the Norwegian Central Bank. The fund has assets totalling more than one trillion dollars invested in equities, bonds and real estate. In March 2019, the GPFG announced that they plan to reduce their investment shares in oil and gas companies. This would affect approximately $7.4 billion of equities in their portfolio but the fund will keep its shares in companies with renewable energy activities in addition to fossil fuels such as the giants BP and Shell. Despite the current pro-ecological environment, the GPFG made it clear that this decision was not due to climate urgency but to a desire to protect against the current uncertainty in the oil and gas sector. Investments in these areas are obviously risks for the climate but also for investors and that is why more and more funds are reducing their vulnerability to a likely permanent drop in oil prices. This would affect, from a financial point of view, the fossil fuel markets. The total stock of the 134 companies affected by this divestment has fallen by $168 million following this announcement, which clearly indicates the possible microeconomic impact of such divestment policies in the fossil fuel sector. The microeconomic impact can be even greater for renewable energy players if these disinvestments are transformed into investments in the areas of sustainability. According to a June 2019 article [9], these disinvestments could reach up to $13 billion and a legal mandate has been issued to push the fund to invest nearly $20 billion in wind and solar energy. This indicates that energy conservation and social pressure will be a major consideration for investors in the coming years.

2 Long-term analysis

We take into account, in this chapter, that disinvestment is taking place in terms of financial resources dedicated to the production of fossil fuel derivatives, but also that producers as well as consumers of grey energy are shifting towards more sustainable energies. This will have benefits for the planet in terms of general pollution. In this chapter we will look at the long-term benefits of such shifts in the energy sector. For this we will look at the "Green Solow Model" and then study the dynamics of a shift from fossil fuels to green energy and investment in technologies to reduce pollution or its impact on the environment.

[8] The Guardian - "Norway's $ 1tn wealth fund to divest from oil and gas exploration" - https://www.theguardian.com/world/2019/mar/08/norways-1tn-wealth-fund-to-divest-from-oil-and-gas-exploration

[9] The Guardian - "World's biggest sovereign wealth fund to ditch fossil fuels" - https://www.theguardian.com/business/2019/jun/12/worlds-biggest-sovereign-wealth-fund-to-ditch-fossil-fuels

2.1 Green Solow Model

In the 2010 article by William A. Brock and M. Scott Taylor [10] it is shown that the EKC (Environmental Kuznets Curve) and the Solow model are intimately linked. The Solow model extended to include pollution abatement technology allows for the derivation of an EKC and convergence towards a balanced growth path. Despite the criticisms of the EKC that will be developed in the following chapter, the development of this model provides answers to the questions of the long-term effects of a disinvestment from fossil fuels or a development in pollution abatement technologies. The model introduced in this paper will be summarized below, and to begin with it is important to define how pollution will be represented in the Environmental Solow model. Emissions are defined as a constant part of an industry's output:

$$Emissions = \Omega \times Output$$

The interest of this paper is to show the effect of the addition of a pollution abatement technology on the different variables of the model which means that the emissions E are a constant part of the economic activity F minus the reduction due to the pollution abatement technology A which depends on the economic activity as well as the efforts of the economic activity to reduce pollution F^A:

$$E = \Omega(F - A(F, F^A))$$

The addition of the emissions variable is important for the derivation of the EKC as well as the balanced growth path in the Green Solow Model, but it lacks the necessary definitions of the capital and income equations. Income Y, the evolution of capital K over time, population growth L and the growth of the variable that explains the share of labour increasing technical progress B are defined as follows:

$$Y = F(K, BL)$$

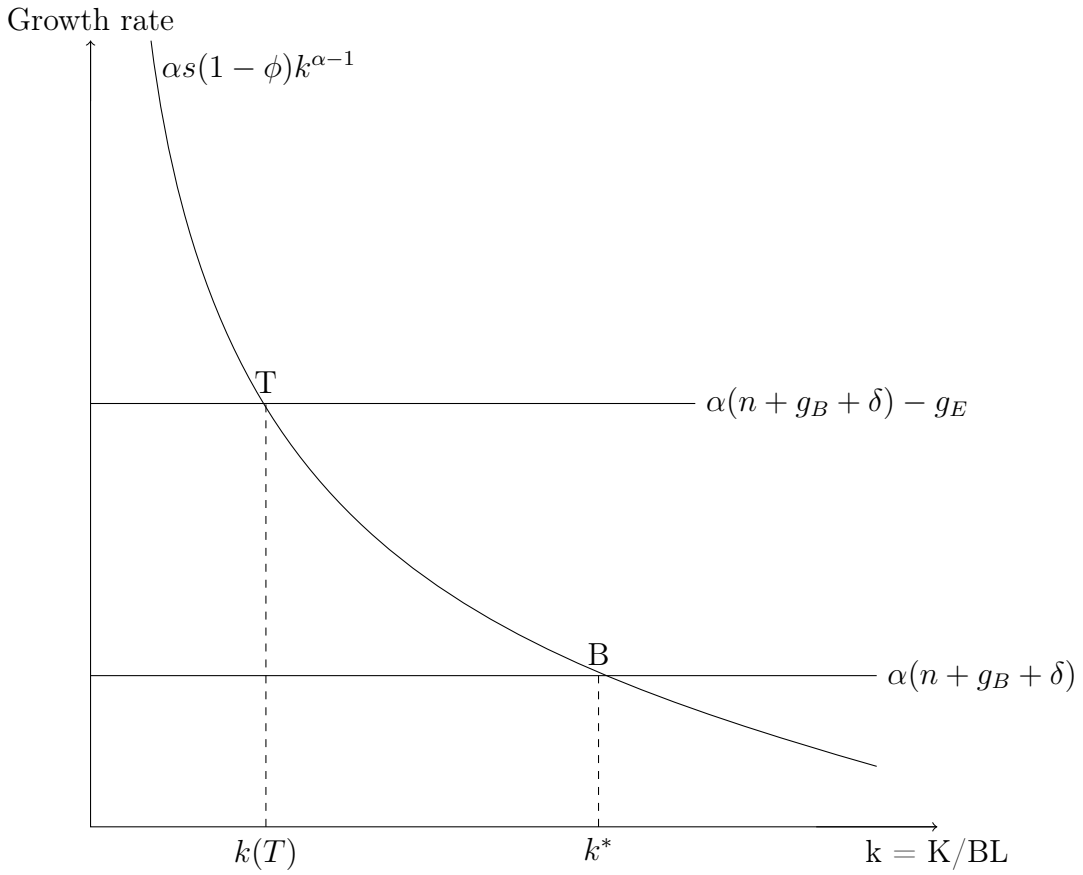
$$\dot{K} = sY - \delta K$$

$$\dot{L} = nL$$

$$\dot{B} = g_B B$$

In the above equations, s is the fraction of income that is saved, δ is the coefficient of capital depreciation, n is the coefficient of population growth, and g_B is the coefficient of growth of the R&D labour share. From these equations, William A. Brock and M. Scott Taylor develop two interesting graphs: The growth rate representation of the Solow diagram and an EKC (Environmental Kuznet's Curve). The set of graphs 7 allows an understanding of the link between growth and emissions in an industry over the long term.

[10] William A. Brock & M. Scott Taylor - The Green Solow Model - `https://link.springer.com/article/10.1007/s10887-010-9051-0`



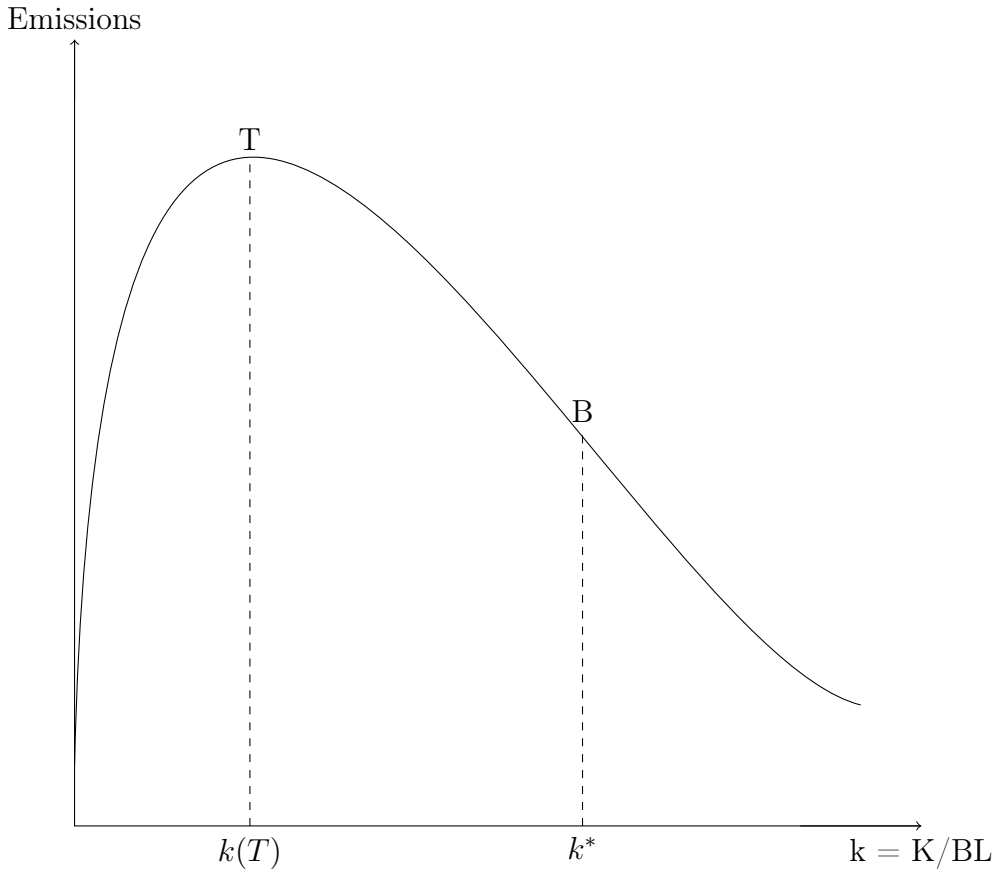


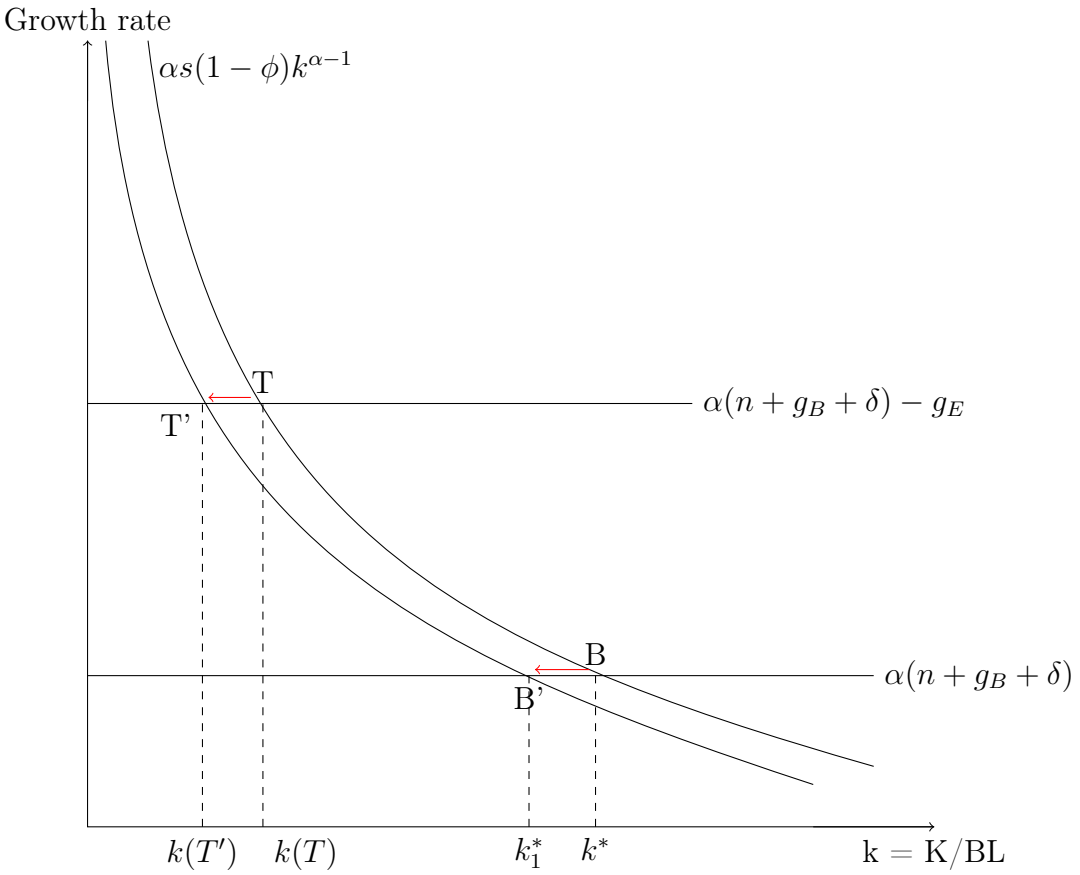
Figure 7: Green Solow Model - Growth Rate Representation of the Solow Diagram & Environmental Kuznet's Curve

We notice on the second graph that as capital increases, emissions will rise to a peak and then, from a certain capital $k(T)$, emissions will start to decline despite the fact that effective per capita output will increase. Investment in pollution abatement technologies will offset, from point T, the pollution created by industry. This behaviour occurs if the starting capital is low enough, and if the $k(0)$ capital is already high, emissions may decrease monotonically.

An important proposal of the article is as follows:

If growth is sustainable and $k(T) > k(0)$, the growth rate of emissions is positive but becomes negative in finite time. If growth is sustainable and $k(0) > k(T)$, the growth rate of emissions will be negative for any t. If the growth is unsustainable, the emissions growth rate declines over time but remains positive for any t.

This proposal is important because it explains the need for growth to be sustainable in order to have, in a finite future, a decrease in emissions and therefore an industrial environment that promotes more sustainable development and meets the challenges highlighted in the introduction. The Environmental Solow model demonstrates that a more restrictive environmental policy cannot transform a path of unsustainable balanced growth into a sustainable ECS. However, such a policy will have an impact on our model over the time it will take to reach the T point and therefore the point at which emissions will start to decrease with the effective capital that will increase. Specifically, a tightening of environmental policy, which could result in an increase in pollution abatement technologies, would push the curves of the 7 graph to the left. This means that the time t to reach the T (peak emissions) and B points would decrease significantly.



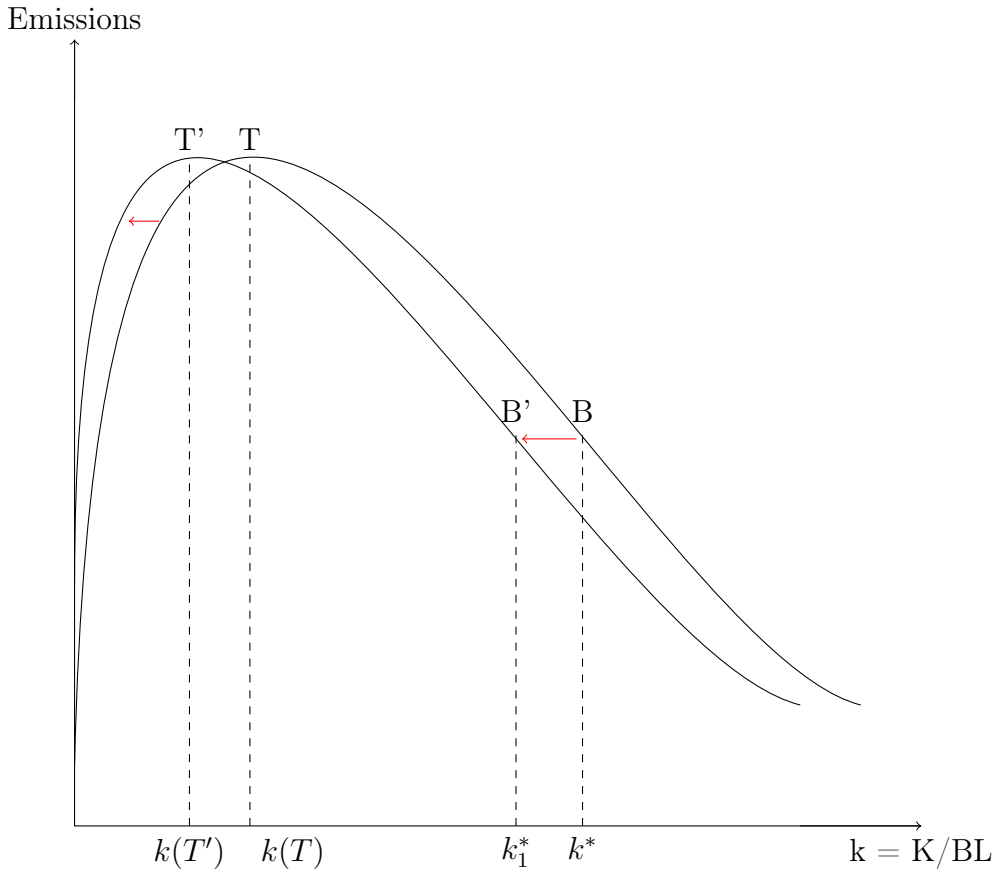


Figure 8: source: Green Solow Model

By analyzing the graph 8, the peak emissions at the T' point will not necessarily be lower than the peak emissions at the T' point before the restrictive environmental policy, but the time to reach the T' point will be lower. The effective capital will also be lower to reach the same level of emissions as before, but this is not necessarily due to pollution abatement technologies that directly reduce emissions, but rather to the fact that the investments that go into these technologies do not go into industry and therefore do not drive growth as much as in our first case. So we conclude that an increased intensity of investment in pollution abatement technologies will shift the peak of emissions to the left and therefore be reached earlier but will have no long-term effect on the rate of growth of emissions.

Using the article explaining the transition impacts of an environmental policy in an endogenous growth model of A. Lans Bovenberg and Sjak A. Smulders [11], the conclusions drawn are interesting. This article takes the analysis one step further and demonstrates the importance of the type of benefits created by a more restrictive environmental policy. Indeed, the growth effects of such an environmental policy depend on whether the benefits of a cleaner environment are in the form of higher productivity of non-environmental inputs into industry (public production factor) or in the form of infrastructure (public consumer goods).

The important contribution to the analysis of long-term disinvestment from fossil fuels from this paper is as follows. If the benefits of a restrictive environmental policy are in the form of consumer public goods, growth will decline in both the short and long term. On the contrary, if the benefits are felt through productivity growth in the production process (in the form of public production factor), long-term growth will increase and short-term growth will not be affected if the ecological system adjusts quickly to shocks, which would allow natural capital to accumulate rapidly.

In conclusion, the Environmental Solow model demonstrates the ability of restrictive environmental policies to accelerate the decline in emissions in a society. This is done through investment in pollution abatement technologies that produce fewer emissions per unit of effective capital above a certain level. This finding is important because it explains how to accelerate the ecological transition, but it is also crucial to understand the effect of such policies on the long-term growth of the same society. Indeed, reducing emissions is crucial but growth should not suffer too much, and to analyze the effect of a policy aimed at disinvesting in fossil fuels and investing in pollution abatement technologies, see article in A. Lans Bovenberg and Sjak A. Smulders is interesting. It explains the importance of having the benefits of such a policy in the form of an increase in the public factor of production and not in public consumer goods. This would, in the worst case, increase long-term growth by decreasing it in the short term and, in the best case, increase growth in the short and long term.

2.2 EKC Reviews

The results found in the previous chapter are very interesting and encouraging, especially nowadays, as they present, under certain restrictive assumptions, clear solutions to improve the environmental situation without negatively impacting growth. Despite these results, it is crucial to remain critical and there are several issues that will be the main points of this chapter.

The Environmental Kuznet's Curve (EKC) is very controversial in the economic field for several reasons [12]. The first is that pollution is, in reality, not only a function of income or production but also

[11] A. Lans Bovenber & Sjak A. Smulders - Transitional Impacts of Environmental Policy in an Endogenous Growth Model - International Economic Review, Vol. 37, No. 4 (Nov., 1996), pp. 861.893 - `https://www.jstor.org/stable/2527315`

[12] Environmental Kuznet's Curve - Tejvan Pettinger - `https://www.economicshelp.org/blog/14337/environment/environmental-kuznets-curve/`

depends on a multitude of other factors such as the effectiveness of state regulations, the development of the economy or population levels. According to a study [13], Singapore, Switzerland and Norway are the countries in which state regulations are the most effective and therefore in which an environmental restriction policy could have an impact as explained in the Environmental Solow model, whereas the results would be much more vague in countries at the bottom of the list such as Somalia, Haiti or Yemen. Another criticism of the EKC and of environmental policies in general is the fact that many so-called developed countries are reducing their industrial production and seeing growth in services but are importing more and more goods from so-called developing countries. Developed countries would therefore see a decrease in their emissions and pollution but this would be compensated by the increase in these factors in countries with an economy based on industry and exports, not on services. A country's EKC would therefore be due to an export of their pollution but, overall, there would be no real reduction in pollution. A final important criticism is the lack of empirical data supporting the EKC, as countries with the highest GDP also have the highest CO_2 emissions.

2.3 Limitations of the long-term analysis

The models used in long-term analysis have limitations. The criticisms of the EKC were presented in the previous chapter, but one important question remains in relation to the Green Solow Model: What is the basis for the idea that over time emissions will decrease with the increase in capital? Indeed, these effects can come from several sources. A first would be a restriction of environmental policies forcing fossil fuel producers to reduce their emissions. A second would simply be the fact that, as capital increases and society becomes more aware, investment in technologies to reduce emissions increases. In any case, one must take into account the assumption that society will take the necessary actions to improve technologies or reduce emissions. Whether emissions decrease after a certain amount of capital has been invested depends very much on the initial values of the $B(0)$, $\Omega(0)$ or s and ϕ model. In the Green Solow Model, an important point is put on the idea that growth must be sustainable, which means that it must be able to be maintained in the long term without endangering future generations, but it also has other definitions and this is not stated in the Green Solow Model article.

The main hypothesis that can be criticized in the Environmental Solow model is that technological progress in pollution abatement technologies is highly related to a country's overall technological progress. This means, therefore, that the reduction of emissions passes through technological progress that will create technologies that can improve production and reduce emissions to the point of offsetting the pollution produced from a certain level of capital. So we see the limitation of this model in the fact that technological improvement does not necessarily mean that scientists will find more effective methods to reduce pollution or to reduce emissions.

3 Short-term analysis

After the long-term analysis of the improvement of the environment due to such disinvestment, we will look at the benefits and consequences of such disinvestment in the short term, i.e. over a period of a few months or even a few years. This analysis will be divided into a financial analysis and more precisely the main reasons for this disinvestment as well as the financial benefits for fossil fuel investors to liquidate their assets, and then into a macroeconomic analysis of the specific case of Saudi Arabia, the largest oil producer. These two analyses provide a clear view of the possible situation, in the short term, of disinvestment in fossil fuels. The motivation behind this chapter is that, having seen the

[13] Government Effectiveness - Country rankings - `https://www.theglobaleconomy.com/rankings/wb\_government\_effectiveness`

long-term benefits of such disinvestment in fossil fuels on growth and the environment, there are also short-term risks, particularly for industries that depend mainly on fossil resources as a major part of their exports. There is also a certain consensus that disinvestment in fossil fuels would be an extremely costly operation that no country could afford and it is therefore interesting to verify whether these claims are well-founded.

3.1 Financial Analysis

More and more companies and private individuals are interested in disinvesting in fossil fuels in order to build a portfolio free of carbon-related investments. This chapter will look at the reasons why so many asset owners are disinvesting in fossil fuels based on the IEEFA (Institute for Energy Economics and Financial Analysis) article [14]. As seen in the introduction, the announcement by the Norwegian pension fund (GPFG) to start their divestment from fossil fuels created a shock in the financial markets and many other funds followed.

The fossil fuel sector is shrinking and it is becoming essential to be rational when considering the choice of disinvestment. In this chapter we will only examine the financial arguments of disinvestment in fossil fuels without taking into account the ecology or ideology of the players. Moreover, ecology is not the only factor that increases the risks of investment because conflicts between producing nations, innovation and cultural change are just as dangerous. On top of that, future environmental policies are a non-negligible risk for financial actors.

For a long time, the fossil fuel sector was a safe and profitable investment in the long term, but since the oil crisis of 2014, things have changed. Indeed, the performance of the oil indices has clearly disappointed and underperformed compared to the overall index average. The coal sector is suffering even more as it has gone from 50% of the electricity generation in the US at its peak to minus 30% today, and this figure will decline further over the years. For these reasons, it would be rational to worry about its fossil fuel portfolio.

Another important argument is the shift in the cause of economic growth from an energy-intensive industry to a service-based economy that requires advanced technologies but is less energy-intensive. So-called developed economies have growth rates that depend less and less on the energy industry and developing economies have more and more opportunities to improve their growth by reducing their energy costs with renewable energy projects around the world. It is interesting to note that the countries that will have the greatest growth by the middle of the century will be China and India, which will also be the countries with the highest decline in energy use intensity[15]. The huge advantage of the fossil fuel sector was our society's dependence on fossil fuels to power our cars, airplanes and produce all the products needed for good growth.

The "too big to fail" argument, which is widely used nowadays, is unfortunately no longer usable for companies producing fossil fuels. With the various arguments seen above, it is clear that these firms are not too big to fail because environmental policies, increasing competition and falling demand will not do this declining field any favors.

To conclude this chapter on the financial situation of the fossil fuel sector, it is clear that disinvestment in this sector is not an action reserved for environmentalists but for any rational actor. The

[14]The Financial Case for Fossil Fuel Divestment - IEEFA - `http://ieefa.org/wp-content/uploads/2018/07/Divestment-from-Fossil-Fuels\_The-Financial-Case\_July-2018.pdf`

[15]ExxonMobil. 2018 Outlook for Energy: A View to 2040. p. 60.

social pressure on environmental policies, the tensions between countries producing these energies and the analysis of the last decade of this sector are undeniable arguments for the loss of power in this field. Despite the costs of such disinvestment, many investment funds have decided to take the step of rationality and limit the risks of their portfolios to the uncertainty hanging over the energy sector and goods derived from oil, gas and coal.

3.2 Macroeconomic Analysis of Saudi Arabia

Since Saudi Arabia depends mainly on the oil industry, it is interesting to study its case to see the effects of a possible global disinvestment from fossil fuels that could result in a global drop in oil imports, which would have a major impact on the country's economy. Indeed, we saw in the previous chapter that the arguments for disinvestment in fossil fuels, and therefore oil, are multiplying, which could create major problems for the countries that produce these energies, which generally depend heavily on exports from this industry.

Saudi Arabia is the main country, along with the United States, producing oil but, unlike the USA, their economy is completely dependent on this sector. Indeed, 90 percent of their export revenues come from the oil sector (oil or oil-based goods), 87 percent of state revenues come from this sector, which represents nearly 42 percent of their GDP. These figures are monstrous and give a first idea of the possible impact of a drop in demand for oil, or even a total disinvestment from fossil fuels. For these reasons, it is interesting to see the impact on their economy and this will be done using the tools developed in the course of macroeconomics, which are the IS/LM and WS/PS models. It is obvious that the analysis is based on very simplified models that do not represent reality but give an idea of the potential impact of disinvestment from fossil fuels on the economy of this country.

In the model we will use to analyze the impact of fossil fuel disinvestment on Saudi Arabia, the Y income is defined as follows:

$$Y = C + I + G + X - M$$

With C consumption, I investments, G government expenditures, X exports and M imports. In the case of the analysis of a disinvestment of fossil energies in Saudi Arabia, we will be interested in a shock on foreign demand which results in a fall in exports X which depend mathematically on the foreign product Y^* (positively) and the real exchange rate ϵ (positively). This decline does not originate from a decline in the foreign product Y^* or a decline in the real exchange rate ϵ, but simply from the fact that the energy use of countries that used to be oil importers has changed and has become less dependent on oil products, implying that their imports will depend less on Saudi Arabia, therefore Saudi Arabia's oil exports will decline. The effect of a decrease in exports can be analyzed on the graph **??**.

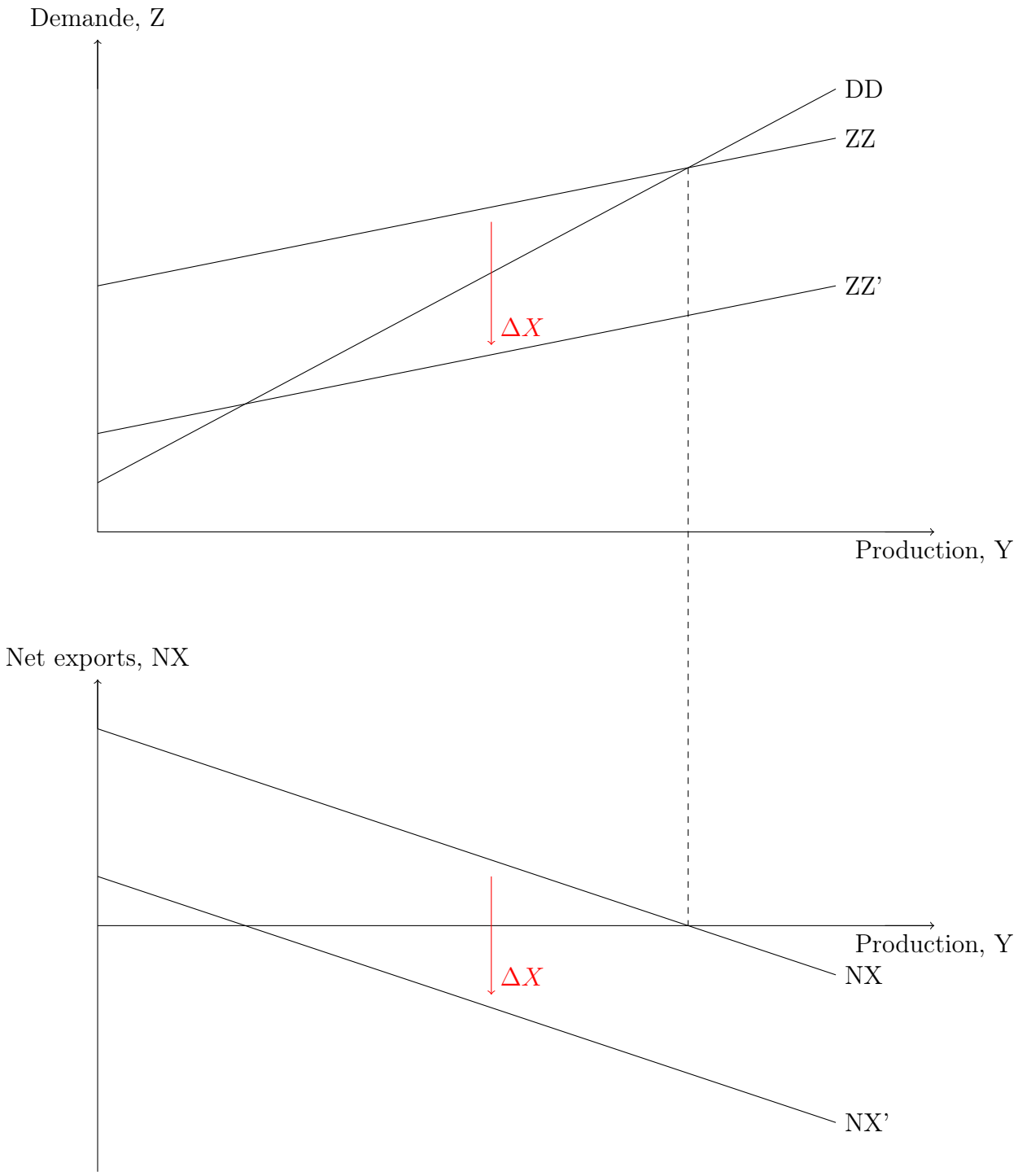


Figure 9: Foreign demand contraction - Equilibrium product

A decrease in foreign demand leads to an equivalent difference in the demand for domestic goods, which explains why the ZZ curve slides downwards. The effect on GDP Y is a net decrease as well as on imports M. The trade balance deteriorates because the decrease in imports does not sufficiently compensate for the decrease in exports. By doing an analysis of the goods market with the IS/LM model (investments and savings/liquidity preference and money supply) we notice the same effect on GDP and this is shown on the graph 10. Indeed, the IS curve will shift downwards on the left during a decrease in exports which will lead us to find a new B equilibrium. This new equilibrium has a lower Y' income level than before the export contraction and the i interest rate will also fall. For its part,

the LM curve is not influenced because exports do not affect the currency market and the demand for liquidity.

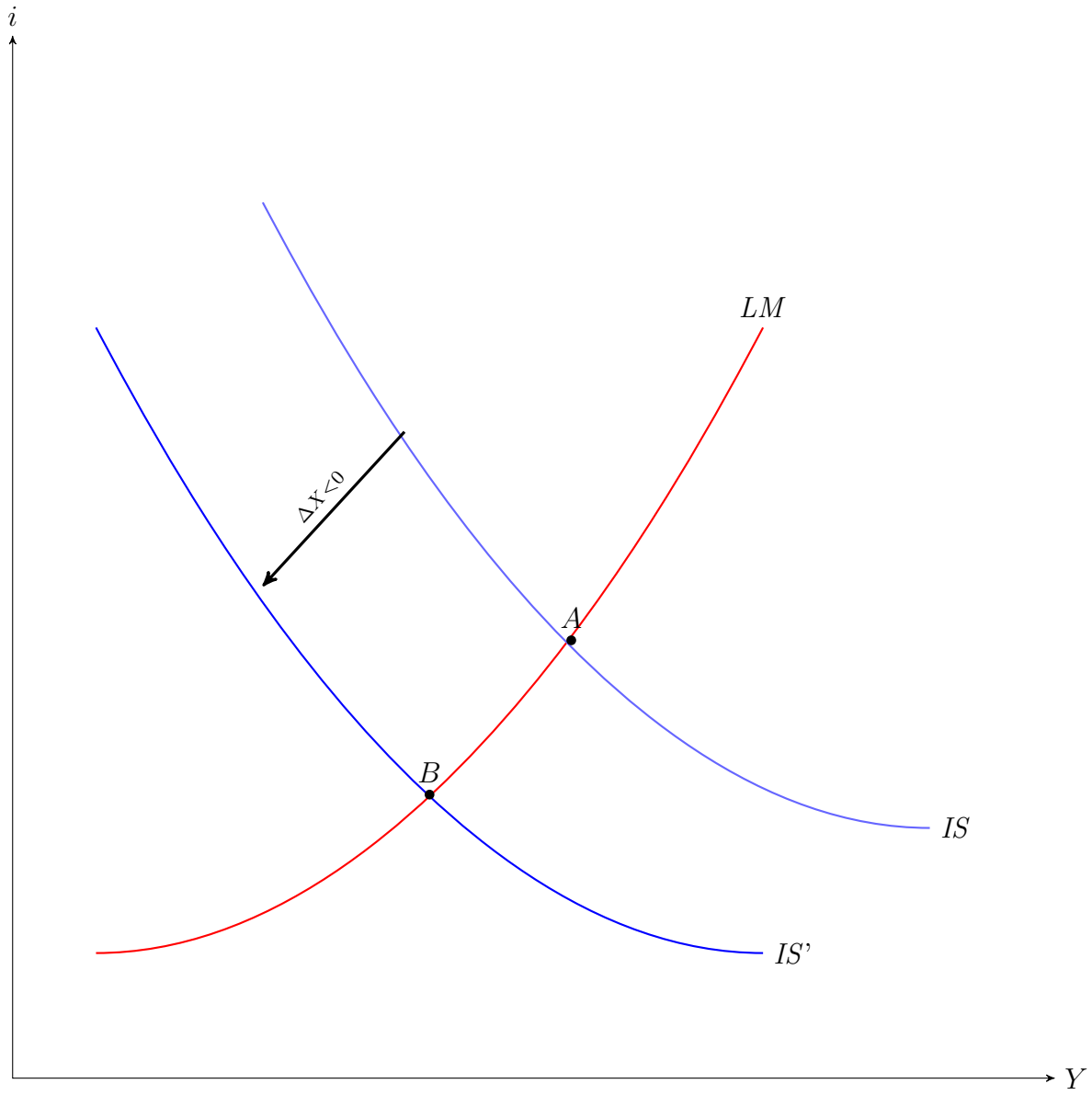


Figure 10: Foreign demand contraction - IS/LM

The country's income will fall along with exports, which means that consumption will also fall as it depends on income. Through the Keynesian multiplier, both income and consumption will decrease even more. We do not deal with the quantification of such impacts in this article but it is obvious that the effects can be devastating on Saudi Arabia with such a dependence on fossil fuels for its exports. In addition to an extremely negative effect on aggregate demand, it is interesting to use the WS/PS model to analyze the impact on aggregate supply.

We can use Okun's Law to understand the difference in unemployment following a shock to exports. Okun's Law, named after Arthur Elvin Okun[16], is an empirical observation of the correlation between

[16]HEC Lausanne - BSc 1 Macroeconomics - Okun's Law

a change in a country's output and its change in unemployment. Mathematically, this law is expressed as follows:

$$\frac{\overline{Y} - Y}{\overline{Y}} = c(u - \overline{u})$$

Y is current output, $\overline{Y}$ is natural GDP, u is the current unemployment rate, $\overline{u}$ is the natural unemployment rate, while c is a constant that acts as a factor transforming variations in the unemployment rate from its natural level into variations in a country's output. This formula can be complicated to use in practice because structural levels of output and unemployment can only be estimated and not measured, but there is a more common formula that expresses output growth rates in relation to unemployment.

$$\frac{\Delta Y}{Y} = k - c\Delta u$$

This equation is useful for expressing year-to-year changes in output relative to changes in unemployment, and vice versa. Okun's Law, explaining a negative correlation between a country's Y output and its u unemployment rate, indicates that a drop in Saudi Arabia's GDP due to a decrease in foreign demand for oil will cause unemployment in the country to increase.

Based on an article by Mouldi Ben Amor and Mustapha Ben Hassine entitled "The relationship between unemployment and economic growth: is Okun's Law valid for the Saudi Arabia case?" [17] it is explained that, in the long run, a 1 percent decrease in real output would result in a 0.33 percent increase in unemployment. This article is particularly interesting in the idea of quantifying the effects of a disinvestment from fossil fuels that would cause Saudi Arabia's foreign demand for oil to fall, which would be the next step for a future article on disinvestment from fossil fuels.

To conclude this chapter, it is clear that Saudi Arabia is at great risk of disinvestment in fossil fuels due to its unparalleled dependence on the production and export of petroleum products. It is therefore a necessity for the country to diversify in order to avoid an impossible situation in the event of a rapid drop in the external demand for oil. The economists of Saudi Arabia are aware of this and that is why the country has launched a programme called "Saudi Vision 2030" aimed at reducing its dependence on oil and diversifying its economy. Numerous projects financed by the Saudi Arabian Public Investment Fund (PIF) aim to develop public sectors such as health, education and tourism.

3.3 Dutch Disease

The question that arose during the macroeconomic analysis of a disinvestment from fossil fuels in Saudi Arabia was whether there was not a positive point, economically speaking, in stopping its dependence on oil products. From this point of view, the concept of Dutch Disease is interesting to study in the case of Saudi Arabia.

In the 1960s[18], the Netherlands discovered large reserves of natural gas in the North Sea, which allowed the country to become rich quickly, but the consequences were not long in coming. Indeed, sectors other than natural resources became less competitive and the impact on the economy was not negligible. This effect was therefore called "Dutch Disease". The Dutch Disease is the negative effect of

[17] Mouldi Ben Amor & Mustapha Ben Hassine - The relationship between unemployment and economic growth: is Okun's Law valid for the Saudi Arabia case? - `https://ideas.repec.org/a/ids/ijecbr/v14y2017i1p44-60.html`

[18] IMF - `https://www.imf.org/external/pubs/ft/fandd/2003/03/ebra.html`

the development of the natural resource sector on other sectors such as industry[19]. In the example of the Netherlands, what happened in detail is as follows. The new access to a huge amount of natural gas has pushed the industry's exports to rise sharply. The effect on their currency, which was the Guilder before the Euro, was an increase in demand for it and therefore the Guilder became stronger. The effect of the strong guilder in the 1960's was a decrease in the international competitiveness of other sectors of the Dutch economy which caused the unemployment rate to vary from 1.1% to 5.1% between 1970 and 1977. In addition to the Dutch disease affecting sectors other than natural resources, the gas sector was problematic because it is a business that requires a lot of physical capital but little human capital. As soon as the economic authorities noticed that the guilder was strong, they decided to keep the interest rate low to try to weaken the national currency but this simply scared investors away from the country.

A development in the natural resource sector can have a negative impact on other sectors such as industry or agriculture and according to the Montaigne Institute, Saudi Arabia suffers from this economic disease. [20]. The country's heavy dependence on oil exports means that in addition to the enormous risk of a drop in external demand for petroleum products, various industries in the country have suffered through the effect of the Dutch disease. These two problems combined show that if the oil sector falls, Saudi Arabia's other industries will not be able to compensate for the losses in the oil sector.

However, if we take the reverse effect of Dutch Disease, this would mean that a disinvestment in fossil fuels implying a decrease in Saudi Arabia's external demand for their oil products would decrease their exports. This decrease in exports would depreciate the national currency, which would positively affect the competitiveness of the country's other sectors, such as manufacturing. The effects explained above can be interesting, especially in order to achieve Saudi Arabia's 2030 vision, which is to revive the other economic sectors and diversify their activities. In this perspective, curing the Dutch disease would make the task of diversifying "Saudi Vision 2030" easier to achieve.

The Canadian Journal of Development Studies has published an article by Robert E. Looney [21] explaining the effect of Dutch Disease on the growth rate of different sectors and his findings are of particular interest. Robert E. Looney notes that this syndrome is present in many economic sectors and draws some illuminating conclusions regarding Saudi industrial policies.

[19]The Economist - Dutch Disease - `https://www.economist.com/the-economist-explains/2014/11/05/what-dutch-disease-is-and-why-its-bad`

[20]Institut Montaigne - Saudi Arabia: Curing the Dutch Disease - `https://www.institutmontaigne.org/en/blog/saudi-arabia-curing-dutch-disease`

[21]Robert E. Looney (1990) Oil Revenues and Dutch Disease in Saudi Arabia: Differential Impacts on Sectoral Growth, Canadian Journal of Development Studies / Revue Canadian Journal of Development Studies, 11:1, 119-133, DOI: 10.1080/02255189.1990.9669386

Table 4

Impact of Dutch Disease Effects on
Saudi Arabian Sectorial Output: Non-Traded Goods, 1965-1985
(constant 1970 prices)

CONSTRUCTION

(1) $CON = 0.10\ GOVIE + 0.08\ YNOE + 0.06\ OIL + 1.15\ INFE - 1.58\ DUTCH$

(2.37) (3.07) (3.48) (7.33) (–2.51)

$RHO = -0.04$, $t = -0.21$ $r2 = 0.994$; $F = 541.21$; $DW = 2.07$

WHOLESALE AND RETAIL TRADE

(2) $WTP = 0.03\ GOVIE + 0.12\ YNOE - 0.68\ DUTCH$

(2.10) (17.32) (–2.32)

$RHO = -0.14$, $t = -0.64$ $r2 = 0.992$; $F = 647.95$; $DW = 2.03$

TRANSPORT, STORAGE AND COMMUNICATIONS

(3) $TSC = 0.05\ GOVCE + 0.05\ YNOE + 0.72\ INFE - 0.13\ DUTCH$

(3.17) (4.02) (6.47) (–0.97)

$RHO = 0.03$, $t = 0.08$ $r2 = 0.997$; $F = 702.84$; $DW = 2.05$

OWNERSHIP OF DWELLINGS

(4) $OD = 0.02\ YNOE + 0.23\ INFE - 0.84\ DUTCH$

(2.51) (3.83) (–4.12)

$RHO = 0.74$, $t = 5.02$ $r2 = 0.815$; $F = 23.53$; $DW = 1.80$

Notes: Equations estimated with Cochrane-Orcutt two stage iteration estimation procedure to eliminate serial correlation. *GOVCE* = expected government consumption; *GOVIE* = expected government investment; *INFE* = expected rate of inflation (non-oil GDP deflator); *DUTCH* = real Saudi riyal/$ exchange rate. *OIL* = value added in the oil sector (1970 prices); *YNOE* = expected non-oil GDP (1970 prices). ( ) *t* statistic; *DW* = Durbin Watson Statistic, *F* = F statistic, *r*2 = coefficient of determination; and *RHO* = serial correlation term.

Figure 11: Impact of Dutch Disease Effects on Saudi Arabian Sectorial Output: Non-Traded Good

The conclusion of this article explains that the presence of the effects of Dutch Disease has indeed been found across many economic sectors. On the other hand, it is also shown that despite the fact that industrial development has been less profitable, the government has policies to resolve the syndromes and that, in the long term, the field of industry will be able to regain its profitability. The scientific literature therefore asks the following question:

If the use of natural resource wealth hurts the productivity growth of other sectors, how should natural resource wealth be optimally used?

This was the field of study of Egil Matsen and Ragnar Torvik in their article "Optimal Dutch Disease" [22] dating from 2003. Their conclusion is that some Dutch disease is always optimal in the sense that a fraction of natural resources should be consumed each period. This puts the notion of Dutch Disease into perspective, which does not mean that having a natural resource-based economic sector will be bad and will have a negative impact on other areas of the national economy. Only the extreme use of the natural resource-based sector is bad for the other sectors of a country's economy.

[22] Egil Matsen & Ragnar Torvik - Optimal Dutch Disease (2003) - `https://www.sciencedirect.com/science/article/pii/S0304387805000623`

3.4 Limitations of the short-term analysis of Saudi Arabia

The IS/LM model used with an open economy is the one presented to 1st year Bachelor students during the Macroeconomics course and has certain limitations. The first limitation is the problem of quantifying the derivations. Indeed, we have seen that a decrease in external demand will decrease exports and thus consumption in addition to GDP but it is not possible with our model to understand by how many percentage points consumption will decrease if the external demand for oil decreases by 1%. Other important points are omitted in this model. Indeed, the structure of Saudi Arabia is not the same as in Switzerland. The different macroeconomic policies will depend on variables that change between countries, such as, for example, the people's confidence in the central bank and the expectations of economic players.

Okun's Law was used to explain that a decrease in GDP relative to its structural level would increase the unemployment rate relative to its structural level. But we have seen that Okun's Law explains that the inflation rate can be determined by inflation expectations as well as the gap between the actual unemployment rate and the natural unemployment rate. In our case, we do not know the inflation expectations and we could assume that expectations are close to reality in the case of disinvestment in fossil fuels. The c coefficient in Okun's law differs from country to country and unemployment will therefore be less influenced in the case of a production surplus for some countries. In the long term, the trade-off between inflation and unemployment disappears since keeping unemployment below the structural unemployment rate requires ever higher levels of inflation.

4 Conclusion

We have seen, in all the previous chapters, the advantages and benefits of disinvestment from fossil fuels. In the introduction, the reasons for this disinvestment were explained, including the climate and social issues that underpin this movement. It is clear that from a scientific but not an economic point of view, fossil fuels are bad for the planet and our society. Social pressure has led many investment funds to withdraw their financial assets from oil, gas and coal. One well-known example is the Norwegian pension fund, with more than 1000 billion dollars in financial assets, which announced the beginning of its disinvestment from the oil sector. It is obvious from countless scientific studies that fossil fuels are bad for the environment, but the aim was to understand, from an economic point of view, the effect of fossil fuels, especially on growth. Wondering whether disinvestment from fossil fuels could not be positive for the economy in addition to the environment and society, many results were explored.

In the chapter on studying long-term growth after a reduction in the use of fossil fuels, we found that long-term growth, as well as short-term growth, will depend on the type of benefit that results from the reduction in the use of grey energy. Indeed, under certain assumptions, long-term growth will improve and short-term growth may not even be affected. In remaining critical of these results, it is clear that for some countries, growth could be improved despite the end of fossil fuel use, but this would be partly due to a transition to a service-based economy that uses very little energy to operate. The problem would therefore be shifted to developing countries whose growth depends heavily on the production of goods rather than services. Ending the use of fossil fuels could therefore have a positive impact on our service economy, but the transition would be much more complicated in countries with little capital and an economy based on the production of goods for the so-called developed countries.

The short-term analysis of a disinvestment in fossil fuels enables us to understand the advantages of limiting the risk to which financial players are exposed and the reasons that may concretely lead

investment funds to reduce their holdings in companies producing oil, natural gas or coal. The analysis of Saudi Arabia shows us the crucial importance for fossil fuel producing countries to prepare for such disinvestment by diversifying their economies in different areas. Despite the limitations of the short-term analysis, it is clear that restrictive environmental policies are fast approaching and could have a devastating effect on a country that depends on oil exports for almost half of its GDP. Despite the risks explained in the chapter dedicated to Saudi Arabia, a glimmer of hope appears when Dutch Disease enters the equation. Indeed, a decrease in the external demand for oil could help other sectors of the country to develop and Saudi Arabia to recover from Dutch Disease.

To conclude this article, it is clear from the evidence that the scientific literature suggests that demand for fossil fuels will contract long before supply is gone. Contrary to the ideas that may be put forward on the subject, many positive, economic points, especially about growth, are revealed when we look at the short- and long-term growth when disinvesting in fossil fuels. The greatest danger is for the countries producing fossil fuels, which are highly dependent on these natural resources, because they must prepare for a probable shock in the years to come by diversifying now. The danger is also present for the still developing countries whose growth could be greatly affected by an ecological transition. The fact that growth can be positively impacted by more limited environmental policies but only under certain assumptions demonstrates the importance of preparing for an ecological transition by thinking deeply about the fundamental issues involved in creating sustainable growth.

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