The Geopolitical Impact of Shale Gas: The Modelling Approach

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Abstract

The US' shale gas revolution, a spectacular increase in natural gas extraction from previously unconventional sources, has led to considerable lower gas prices in North America. This study focusses on consequences of the shale gas revolution on state stability of traditional oil and gas exporting countries in the vicinity of the EU. For this purpose, we developed two separate SD models. The first model was used for assessing the impact of shale gas and energy decoupling on oil and gas price developments. We selected some of these price developments as input scenarios for a second SD model. This SD model was used for assessing the impact of energy price scenarios on countries' economic development, and via the development of unemployment and purchasing power, on state stability. The conclusion of this study was that while shale gas developments may be seen as a part of the standard energy hog-cycle, this may lead to pressure on oil prices, which may cause instability in traditional oil and gas producing countries in the neighbourhood of the EU. Further, the effects of energy decoupling may have an even larger effect on putting energy prices under pressure, thus leading to social unrest.

Keywords: Shale gas revolution, Price scenarios, Social unrest, Scenario Discovery, Uncertainty

1 Introduction

In recent years, a spectacular rise in natural gas extraction capacity from previously unconventional resources has dramatically changed the US' energy landscape, making the country independent from natural gas imports. This development is often referred to as the 'shale gas revolution'. These developments were made possible by the process of hydraulic fracturing, or 'fracking'. As a consequence of the shale gas revolution, American gas prices have dropped strongly, giving a competitive advantage to American industry. The rise in similar oil resources only adds to that advantage.

Presently, the shale gas revolution is still largely an American affair, as outside North America no commercial exploitation of shale gas resources is taking place. This can be explained both by institutional differences between the US and other countries (*e.g.*, resource ownership) and geological differences. However, it seems implausible that in a global energy system, the effects of the shale gas revolution will remain limited to the US. Although LNG trading is limited, shale gas may substitute other, easier transportable energy sources. Eventually, the shale gas revolution may thus have an impact on global energy markets [ref authors].

Price fluctuations may have consequences for the economic situation of traditional oil and gas exporting countries, of which many are heavily reliant on resource rents for supporting there economy. Resource rents are income generated by resource extraction, often calculated as part of GDP. Therefore, fluctuations in resource prices may influence the development of the local economies of oil and gas exporting countries. In turn, worsening economic situations are known to have an impact on population discontent, potentially leading to instability (Collier and Hoeffler 2004, Ross 2004).

The complexity and uncertainty of both the global energy system and national stability make mental simulation difficult. Hence, using a quantitative approach able to cope with this uncertainty and the delays in the system, may be useful. System Dynamics (SD) is such an approach (Forrester 1961, Sterman 2000, Pruyt 2013). Further, many of the factors, including resource figures and depletion paradigms (Tilton 1996), are fundamentally uncertain. Hence, using an approach capable of handling uncertainty in combination with SD models is appropriate. For this purpose, the Exploratory Modelling and Analysis (EMA) methodology can be used (Lempert, Popper, and Bankes 2003, Kwakkel and Pruyt 2013) in an approach similar to Scenario Discovery (Bryant and Lempert 2010, Kwakkel, Auping, and Pruyt 2013). This allows using SD models on both aggregation levels (*i.e.*, the global energy system and country stability systems) in an extended 'what if' analysis (Oreskes, Shrader-Frechette, and Belitz 1994, Kleijnen 1997).

In the field of SD, many examples exist of models regarding energy systems. The most well-known example is of course the Limits to Growth and earlier related studies (Meadows et al. 1972). Further, early models already focus on energy transitions (Naill 1977, Sterman 1981), and externalities of energy economics (Fiddaman 1997). However, in our knowledge no SD study used energy models as a scenario generator for price developments. These scenarios are in essence sets of outcome indicators from particular runs forming an internally consistent narrative about plausible future developments.

Although much of the conflict literature does not naturally fit SD thinking, examples exist of modelling social unrest in SD. For example, Wils, Kamiya, and Choucri (1998) present a model which can be used to examine the development of internal and external pressure related to resource use. Further, Anderson (2011) used an SD model for looking at the effects of counterinsurgency policy in relation to public support and other factors. Finally, Pruyt and Kwakkel ((in press)) compared three SD models about the rise of activism, extremism, and terrorism. In none of these models, however, external price scenarios were used for 'stress testing' state stability.

In this paper, we present a multi-model approach (Pruyt and Kwakkel (in press), Auping, Pruyt, and Kwakkel 2012) using a global energy model to generate energy price scenarios, which function as input for testing via country stability model whether these scenarios may lead to an increase in instability. Hence, we explore the long term effects of shale gas and other unconventional energy sources on the global energy mix, and consequentially plausible energy scenarios. This model fits within an opportunity costs paradigm (Tilton 1996). We present a selection of these energy scenarios, where the focus lies on taking those price scenarios that fall outside the scope of more traditional forecasts of energy prices by for example the EIA and BP (2013, 2012).

These scenarios are than used as input for a country stability model, focussing on economic discontent (*i.e.*, 'greed' in Collier and Hoeffler 2004). As such, the price scenarios are used for ‘stress testing’ country stability for traditional oil and gas exporting countries, more specific those countries in the vicinity of the European Union (EU). These countries are Algeria, Azerbaijan, Egypt, Kazakhstan, Qatar, Russia, and Saudi Arabia.

The setup of this paper is as follows. In next section, we will start with explaining the research approach chosen in this study. We will then present an extended discussion on the model structure of both the global energy model and the country stability model. In the following section we will explain the metrics for choosing 14 price scenarios. Following on this, we will present the results on country stability by taking Russia as an example. Finally, we will discuss the results of this approach and draw conclusions on the geopolitical consequences of the shale gas revolution.

2 Methodology

In this section, we will start with explaining the setup of the study and the use of SD and EMA in an approach similar to Scenario Discovery. After this, we will present the global energy model and country stability model used in this study[1] and a short discussion on model validity.

2.1 System Dynamics and Exploratory Modelling and Analysis

SD (Forrester 1961, Sterman 1981, Pruyt 2013) is a modelling method which is particularly useful for simulating systems which are characterized by strong feedback loops, delays and stock-flow structures.

Exploratory Modelling and Analysis (EMA) is a research methodology that uses computational experiments to analyse deeply uncertain issues (Bankes 1993, Pruyt and Kwakkel 2013). EMA consists of quantitative modelling of the set of plausible models and uncertainties, the process of exploiting the information contained in such a set through (a large number of) computational experiments, the analysis of the results of these experiments, and the testing potential policies for robustness (Bankes 1993, Pruyt and Kwakkel 2013).

EMA can be useful when relevant information exists that can be exploited by building models, but where this information is insufficient to specify a single model that accurately describes the real system behaviour. In this circumstance, models can be constructed that are consistent with the available information, but such models are not unique, which is an important reason for specifying different functions, model structures, or multiple models. These models, combined with parametric uncertainties, allow for computational experiments that reveal how the world would behave if any particular combination of assumptions would be correct. By conducting many such computational experiments, the implications of the various guesses can be explored.

The result of such an approach is in essence an extended ‘what if’ analysis (Oreskes, Shrader-Frechette, and Belitz 1994, Kleijnen 1997) and close to the Scenario Discovery

[1] Parts of the model description have already been published in the report recently published by the authors [ref authors]

approach (Bryant and Lempert 2010). In order to allow assessing the effects of long delays in the system, such as developments in extraction capacity in the global energy model or demographic effects in the country stability model, we simulated both models for the time period between 2010 and 2060.

2.2 Global energy model

The balancing of supply and demand can be seen as the combination of two balancing feedback loops (Figure 1). The first feedback mechanisms is between supply and price. With a price increase, more supply will be possible, while with an increase in supply, the price will decrease. The second feedback is between demand and price, where more demand will generally result in a higher price, while a higher price eventually leads to a decline in demand. Eventually, as the reaction of both demand and supply on the price is delayed, supply and demand will adjust according to the witnessed price levels.

In modelling efforts it is sometimes necessary to introduce exogenous trends, which are almost without exception deeply uncertain. It is thus necessary to explore the consequences of different plausible evolutions of this important factor. For this reason, we needed an exogenous driver for the GDP growth. However, as energy is vital to the functioning of the economy, we assumed that energy prices may also influence GDP growth, which is an endogenous effect. The overall GDP growth is thus partly endogenous. Given the functioning of SD models, the economic growth will lead to exponential growth of the energy demand, as energy intensity forms a linear relation between GDP and energy demand.

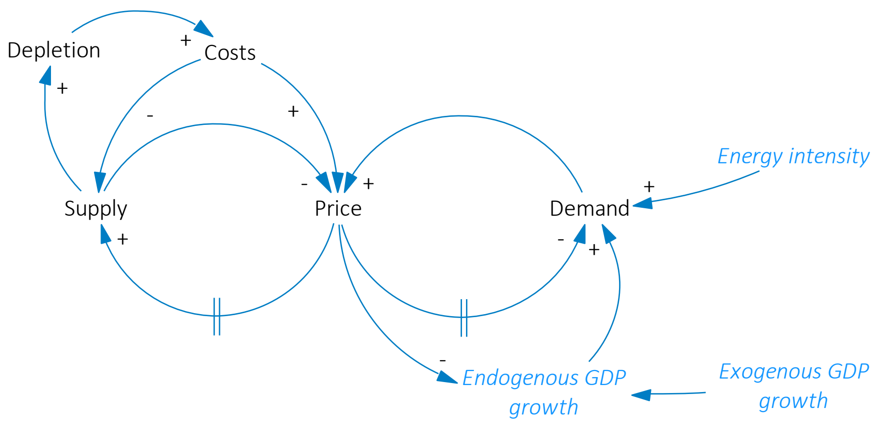

Figure 1. Balancing of supply and demand

The effects of political instability on energy supply, a potential feedback from the instability models, is not considered here. Furthermore, policy measures aimed at changing the composition of the energy mix – in essence the definition of an energy transition – are not considered, besides one driver for the development of renewable energy capacity.

The fully quantified global energy model is subdivided in 5 sub-models, which are mutually linked (see Figure 2). As is visible in this diagram, we look at the demand development, supply development, prices of the different primary energy sources, costs development of the supply, and trade between the different regions. The development of demand, supply, and the prices of the different primary energy sources are important given the feedbacks between supply and demand via the price effect. The costs extraction costs sub-model is important for modelling the effects of depletion on extraction costs. Finally, as a greater availability of gas may lead to a larger share of LNG on the market, it is important to consider trade between the different regions of the tradable resources, in this case gas (LNG), oil, coal, and renewables. Trade of the two remaining primary energy sources, nuclear and hydro, is thus not considered.

In the model, 4 different regions are defined: Northern America (US and Canada), Europe and adjacent regions (Europe, non-European CIS, Middle East, and North Africa), Far East (China, India, Japan, and South Korea), and the rest of the world. The first two regions are defined with the availability of overland gas pipelines in mind. The Far East is presently a major user of LNG.

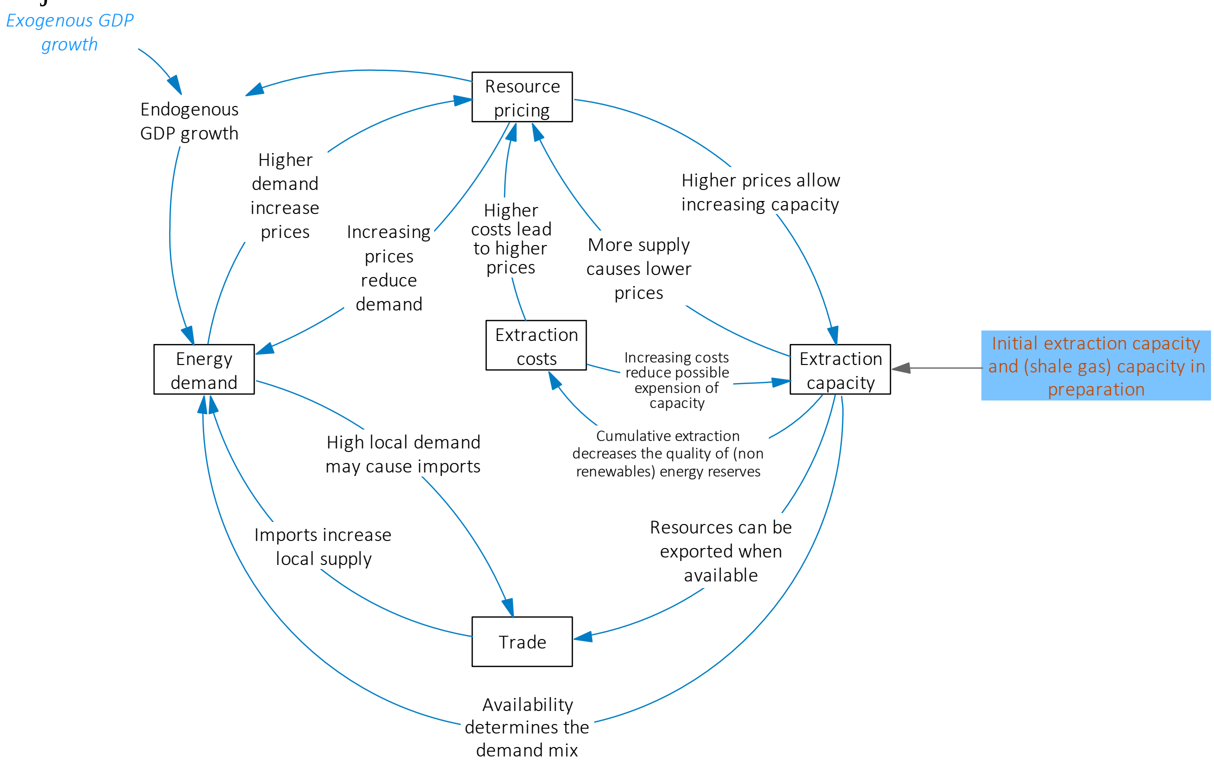

Figure 2. Sector diagram of the energy prices model. Sub models are displayed in a box. External trends are shown in *blue* and *italics*. Relevant initial conditions in *red* with a *light blue* background.

2.2.1 Detailed description

Energy demand

In the demand sub-model (see Figure 3), demand is calculated for different energy sources. We distinguish six different primary energy sources: oil, gas, coal, hydro, nuclear, and renewables. Demand fluctuates as a result of three different drivers:

1. **Substitution**: supply, allocated on the basis of absolute prices, determines an ideal energy demand mix. Part of the energy demand is then substituted to let the energy mix change into the direction of the calculated ‘ideal’ energy mix.
2. **GDP**: energy demand is directly affected by a change in GDP. Decoupling (*i.e.*, an increase in energy efficiency leading to lower growth in energy demand than the economic growth) leads us to apply a small discount on this change. Again, this small discount translates into exponential growth, or in this case more specifically, exponential decay.
3. **Relative price changes**: if prices go up, demand decreases and vice versa. Going from the short term to the long term, this effect becomes more pronounced. This effect is faster in response to prices than the economic growth reduction effect mentioned above.

As was mentioned earlier, economic growth is viewed as at least partly exogenous to the system. More specific, potential economic growth trends are explored with a quasi-random set of waves, which superposed form the exogenous part of the economic growth variable. The potential feedback of energy prices is added to this dynamic value. In the case of rising energy prices, this means that economic growth is negatively affected.

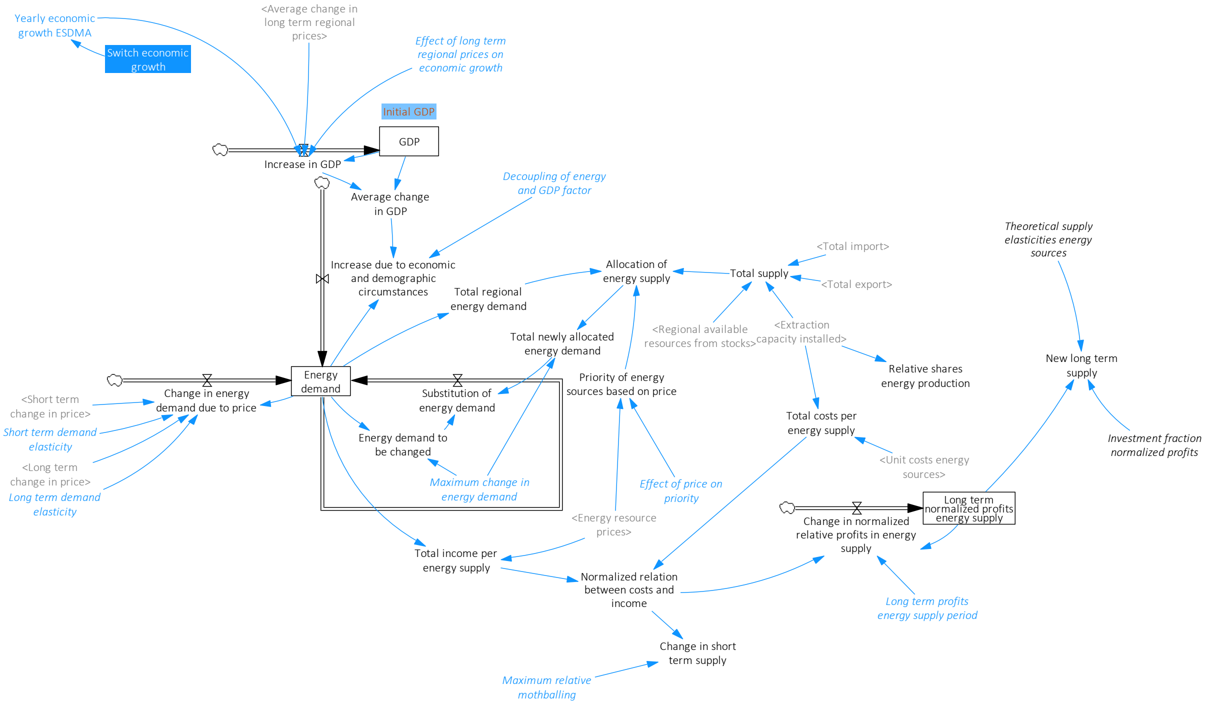

Figure 3. View of the demand sub-model

Extraction capacity

The (extraction) capacity sub-model (see Figure 4) calculates capacities for (extraction) of each of the six energy types. If long term profit margins allow, new capacity is developed and added, where the profit margins are calculated by subtracting the costs from the price, which both have own dynamics. However, this capacity will only become available after a delay. Short term price effects lead to capacity being either mothballed or brought back online.

For energy sources that can be stockpiled (oil, coal, and to some extent renewables), stocks are calculated. These stocks are then used to determine the relative scarcity of the resource in question, and through that, its price. The difference in price dynamics between stockpiled resources and non-stockpiled resources is very large. When stockpiling is possible, overcapacity can be accumulated. The consequence of this accumulation of resources is that the throughput time of stocks increases. As stockpiling is expensive, this has a downward effect on the price. This effect is easily much larger than the actual relative overcapacity which can be calculated by comparing production (or extraction) capacity with the demand, especially as both demand and supply react delayed on price changes. Hence, it is to be expected that resources sold from stockpiles show larger volatility than resources of which essentially production or transport capacity is sold.

The availability of shale gas in the US is incorporated in the model by changing the proposed new gas extraction capacity in Northern America proportional to the increase in shale gas capacity witnessed in the past years. In other regions, the proposed new capacity is within normal proportions, relative to present price levels. As such, we assume that the American situation is part of the initial situation in which we start simulating the primary energy sources system. Other potential non-conventional fossil energy sources are considered to be part of the normal continuum of increasing availability at higher prices.

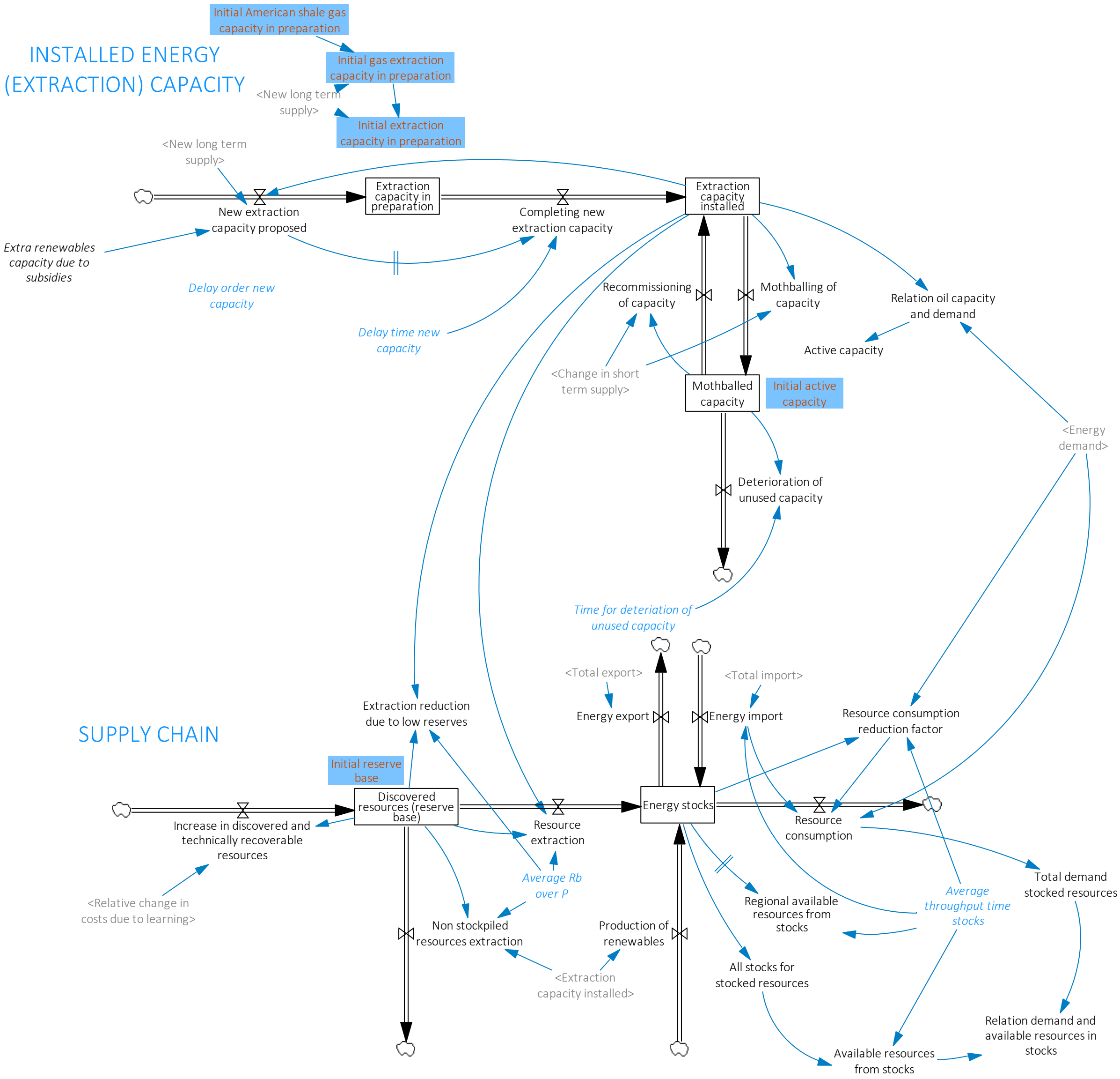

Figure 4. View of the (extraction) capacity sub-model

Extraction costs

Costs are influenced by two drivers: (1) the Energy Return On Energy Invested (EROEI) in the case of non-renewable resources, which decreases when reserves are depleted; and (2) learning effects in the case of *all* resources (see Figure 5). Both are calculated via the ‘cumulative extracted fuel’ (or, ‘other energy resources’). Non-renewable sources will thus initially become cheaper, only to become more expensive after depletion sets in. In the case of renewable resources, learning effects will cause costs to decrease as they are used more often.

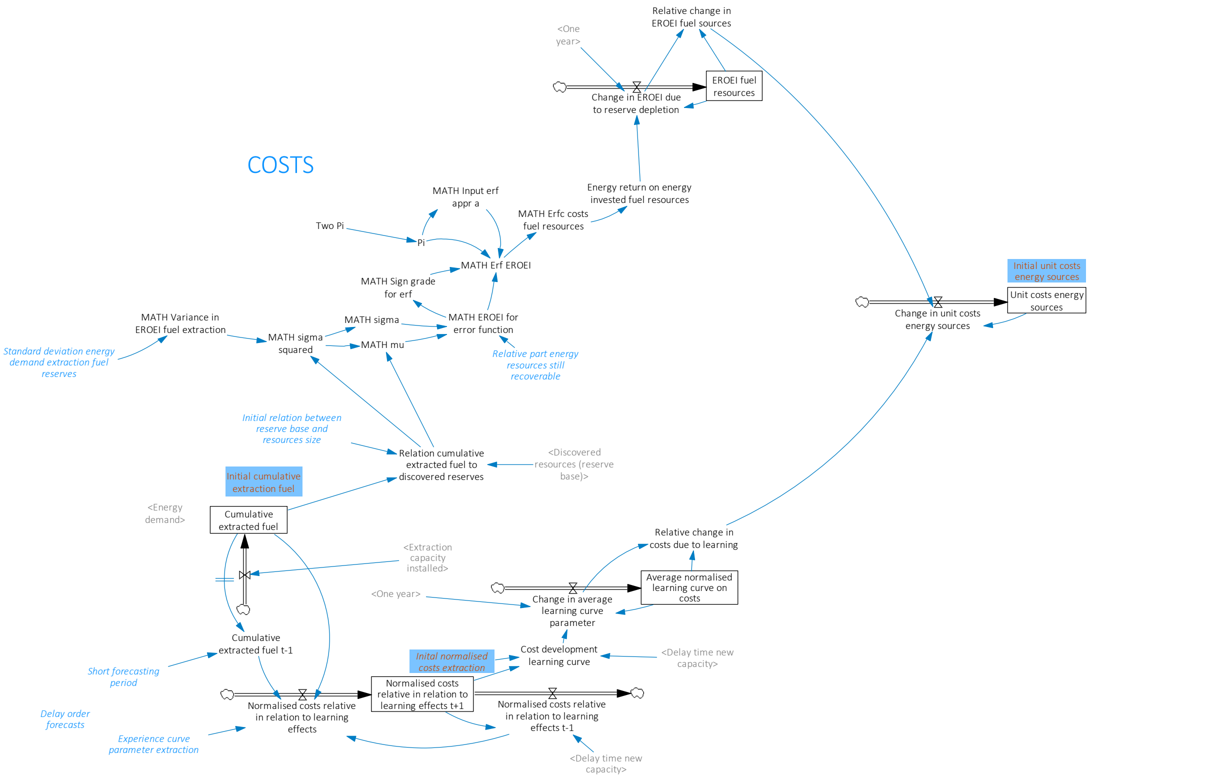

Figure 5. View of the costs sub-model

Energy pricing

Prices are calculated in different ways, depending on the region and the type of energy. See Figure 6 for a graphic representation. For stockpiled resources, stocks are compared to the energy demand by dividing the stock by the shortest throughput time, in order to calculate the available capacity of the stock. The resultant relative shortage or surplus is subsequently multiplied by the unit costs in order to calculate a price. Another mechanism for calculating the price is comparing the (extraction) capacity of the energy source to the demand. The last option is known as a ‘cost-plus’ mechanism, which adds a percentage to the unit cost of the production capacity.

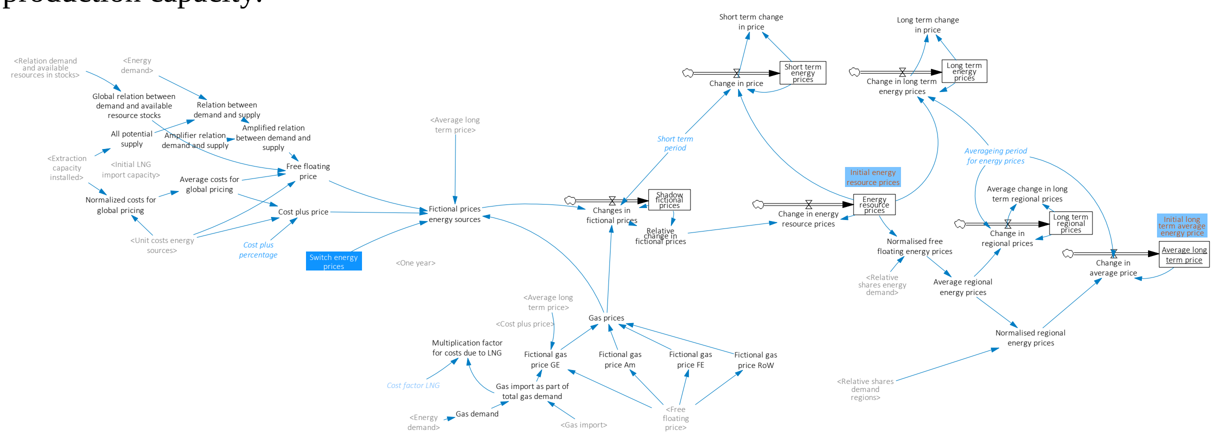

Figure 6. View of the prices sub-model

Trade

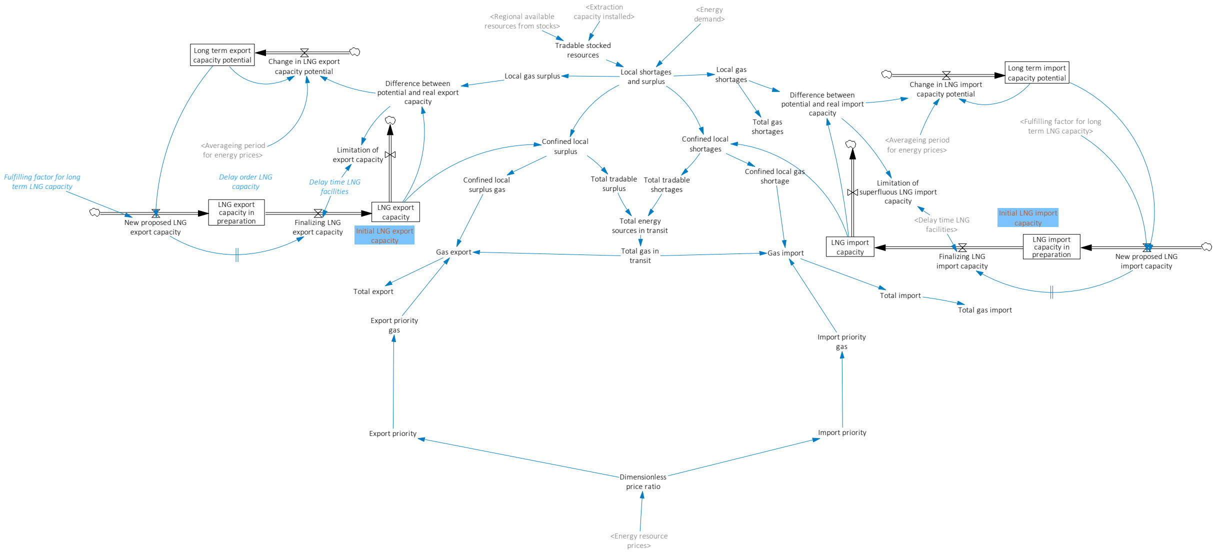

Figure 7. View of the trade sub-model

In this sub-model (see Figure 7), a local surplus and/or shortage of tradable resources (oil, gas, coal, and to some extent renewables) in one region is matched to the existence of a surplus and/or shortage in other regions, causing ex- and imports. The availability of (LNG) infrastructure is considered to be a limiting factor only with respect to gas.

2.3 Country stability model

The impact of oil and gas prices on country stability is largely a one way process (see Figure 8). However, as instability will impact the development of the GDP and the resource extraction capacity, the effect is self-enforcing. Some other, minor feedbacks occur in impacting stability with resource prices. Examples are the effects of population size on the fertility and mortality levels, which may cause a deadlock situation with high population and little development. Another example is the effect that immigration will have on the workforce, and the effect the available workforce has on immigration. A last one may occur when the regime is susceptible for the discrepancy between on the one hand the democratic expectations that the population may have, and the present regime type on the other. However, instability may again counteract this development when the government reacts in a more autocratic way to a crisis in the country.

Within the process of prices influencing instability, however, many factors counteract in either making specifically price de- or increases lead to more instability. Price increases will have a positive effect on government finances, create more employment, but it has an adverse effect on purchasing power. It will depend on the specific conditions in a country, whether the positive or the negative effects will be dominant.

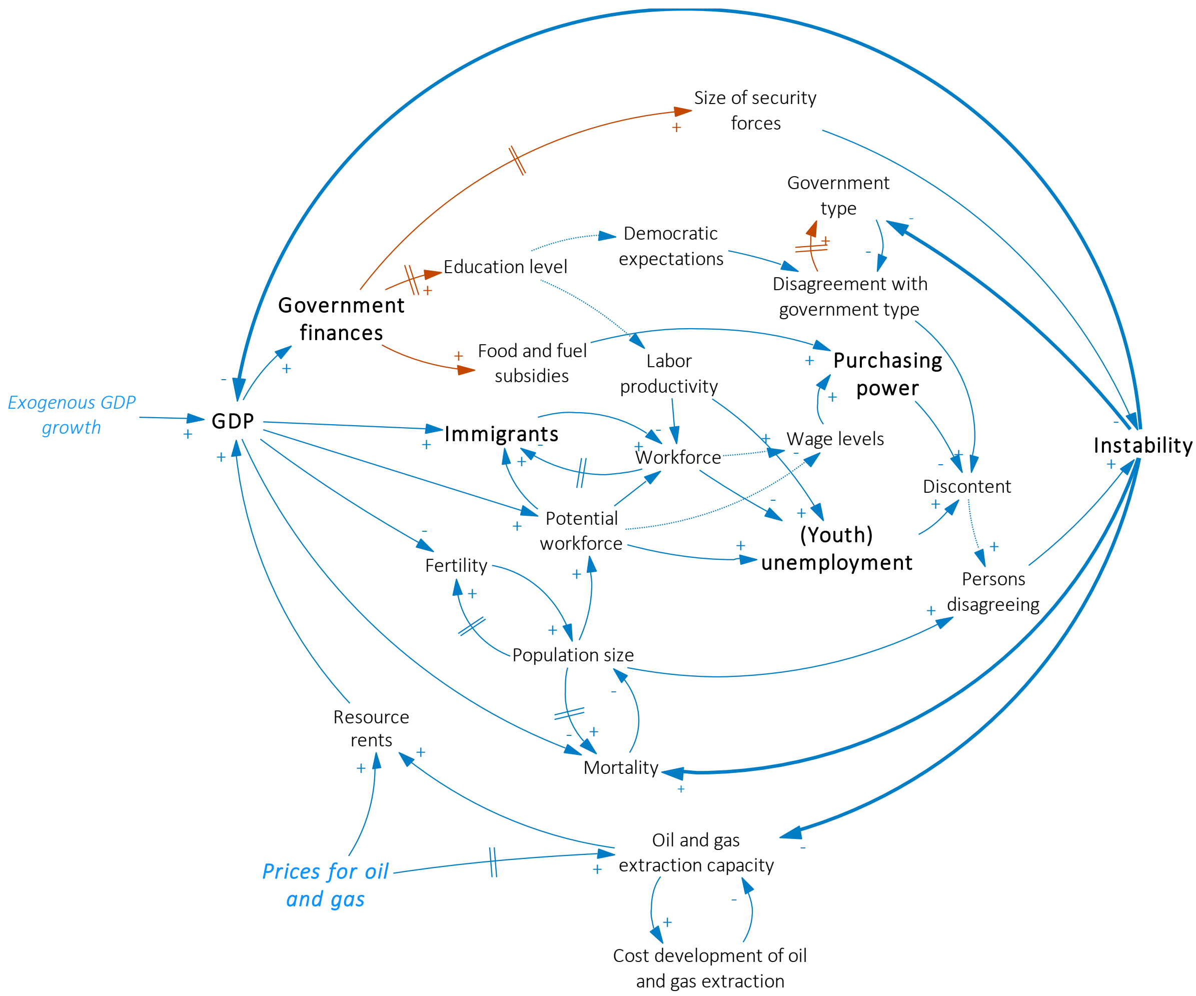

Figure 8. The impact of resource prices on instability. Government decisions have *brown arrows*, important uncertain relations have *dotted arrows*, feedbacks from instability have *bold arrows*, and important variables have *bold typeface*.

Several factors may act as buffers for avoiding potential instability, especially in the case of decreasing price levels. The first one is the availability of financial reserves for the government. When governments use resource rents to build up large financial buffers, these will allow them to maintain fuel and food subsidies in periods of low prices. Not maintaining these subsidies may lead to an unstable situation in the country. Another buffer is the availability of immigrants in the country. With many immigrants, the government may have the opportunity to repatriate the immigrants in order to reduce the unemployment under the domestic workforce.

The fully quantified energy prices model is subdivided in 5 sub models, which are mutually linked (Figure 9). These sectors generally contain several of the factors visible in Figure 8, and as intra-sector feedbacks are not shown in the sector diagram, less feedbacks are visible.

The sector diagram further makes clear that we do not take the effects of nationalism and ethnic conflict into account. We thus focused solely on the direct and indirect effects caused by resource rents in society, instead of taking all potential causes of instability into account.

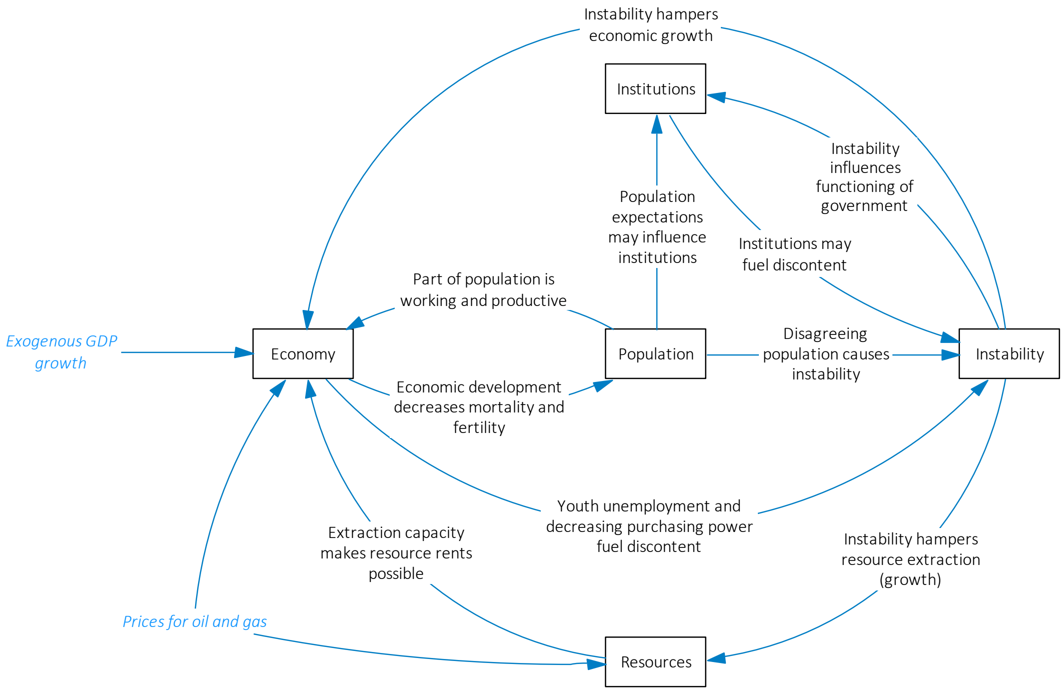

Figure 9. Sector diagram of the instability model

2.3.1 Sector description

Economy

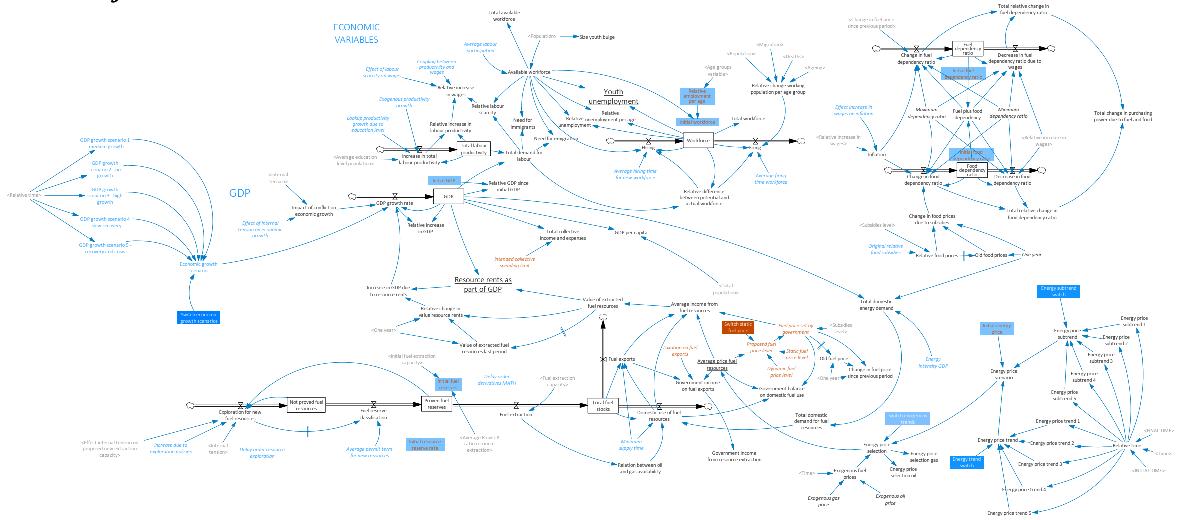

Figure 10. View of the economy sub-model

In this sub-model (see Figure 10), the economic effect is calculated. First, the GDP is calculated by means of an exogenous economic growth structure representing the effects of

external economic circumstances on the national economy. Second, we look at the effects of the changes in resource rents on economic growth. Growth is thus partly endogenously influenced. Resource rents are calculated by multiplying available fuel resources (limited to oil and gas in this model) with the relevant price scenarios. The availability of fuel resources (in this case restricted to oil and gas) is calculated by using a resource supply chain from undiscovered resources to the extraction and finally internal use or export.
The effect on the workforce is calculated through the GDP. This has consequences for both youth unemployment and wage levels. Finally, purchasing power is calculated by looking at the relative change in food and fuel dependency.

Resources
Two things are calculated in the resources sub-model (see Figure 11). First, the development of the extraction capacity for both oil and gas is modelled with a delay on proposed new capacity. Further, the costs of extraction (energy return on energy invested) are calculated in order to mimic the depletion of resources. Compared with the price scenarios, this will determine how much new capacity is being developed.

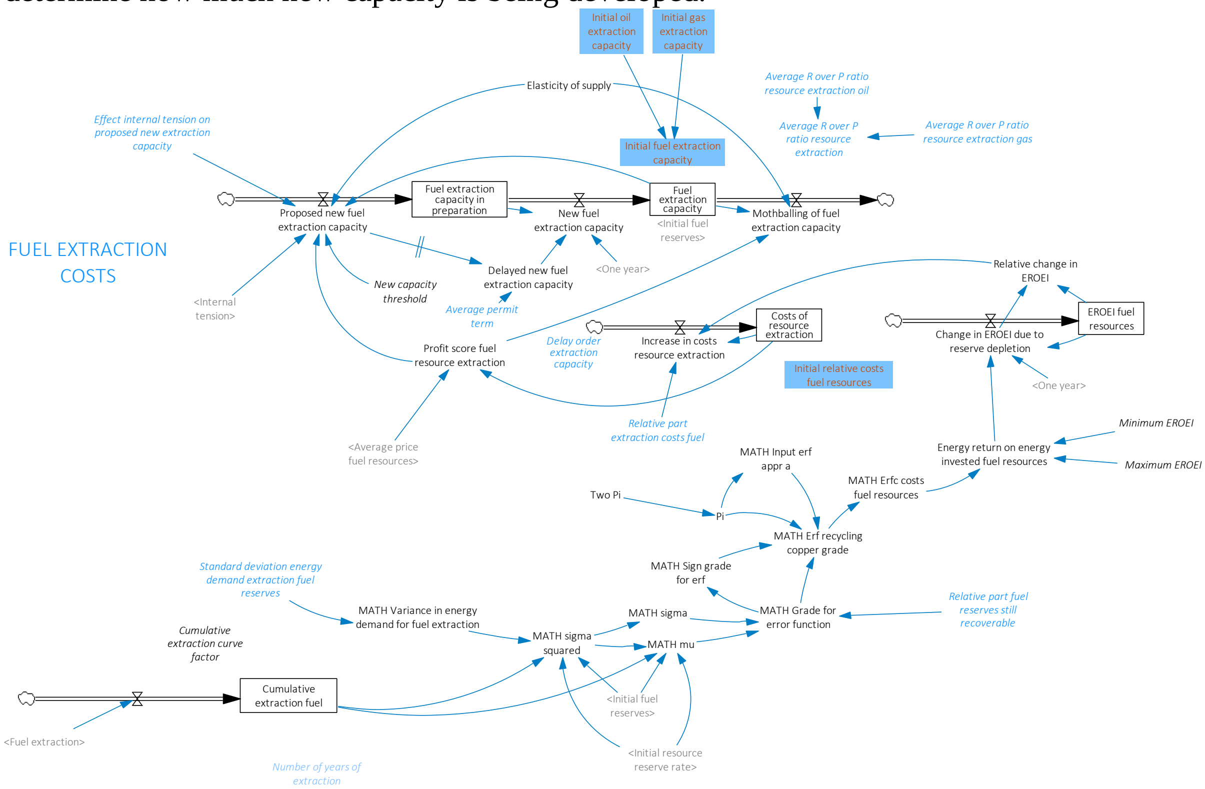

Figure 11. View of the resources sub-model

Population

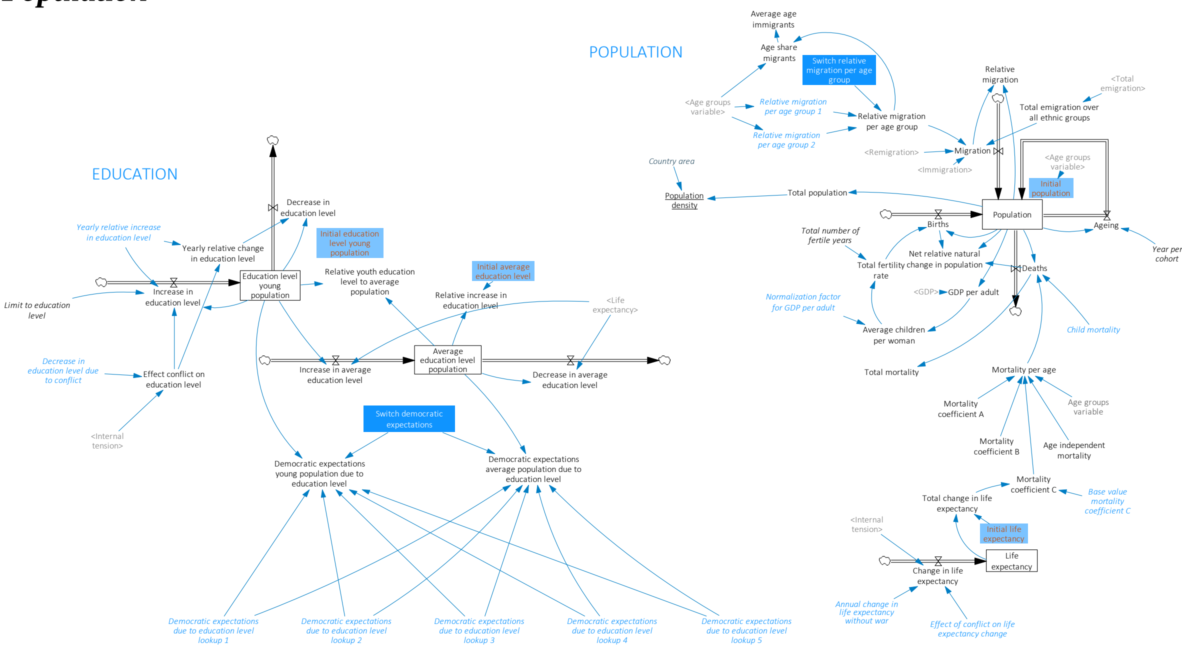

Figure 12. View of the population sub-model

In the population sub-model (see Figure 12), the demographics of the country are modelled. The population is influenced by births, deaths and migration and is subdivided in age cohorts of 5 year each in order to create some precision in the population development. The fertility of women is modelled endogenously with a correlation to the GDP per adult. The death rate is calculated relative to the changes in life expectancy. This variable is influenced both by an exogenous trend factor, as well as by the negative influence (severe) instability has on life expectancy.

Further, the education level of the population is modelled in order to calculate democratic expectations, related to the level of education. This is done both for the total population, as well as the youth. Since the youth was found to be higher educated than the average population in all countries we investigated, this is likely to generate potential for youth frustration.

Instability

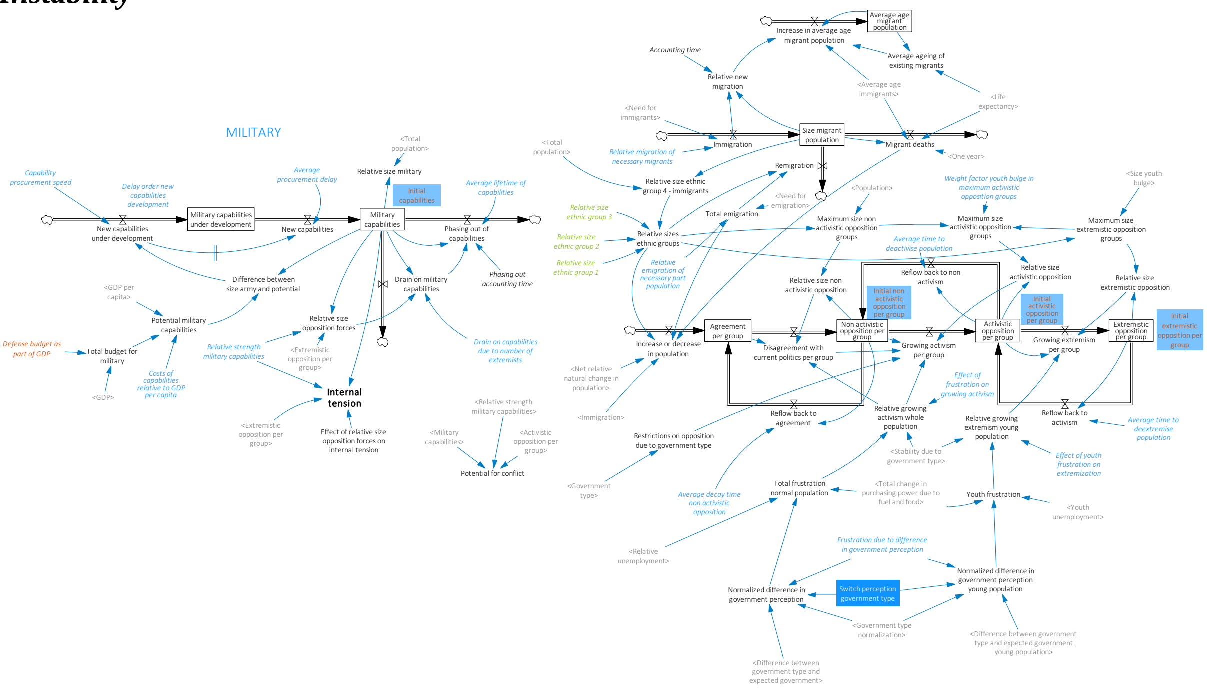

Figure 13. View of the instability sub-model

The instability sub-model (see Figure 13) calculates the amount and level of disagreement with the current situation by the population. The main factors for calculating disagreement are unemployment, purchasing power changes, and changes in the difference between the government type and the expectations of the government type. The amount of disagreement at the highest level (i.e., willingness to use violence against the government) is compared to the size and force of military capabilities.

2.4 Institutions

In the institutions sub-model (see Figure 14), we calculate potential shifts in the country's state form. The model follows the polity scores between -10 (pure autocracy, *e.g.*, Saudi Arabia) and +10 (pure democracy, *e.g.*, North-western European countries). Governments may, or may not, decide to follow the democratic expectations of the population. The polity score has an influence on the stability of the government. Further, the absence of violence decreases in the case of instability. A lower value for the absence of violence leads consequentially to a lower value for government legitimacy. Finally, government finances are calculated in order to be able to know when for example fuel subsidies will become untenable.

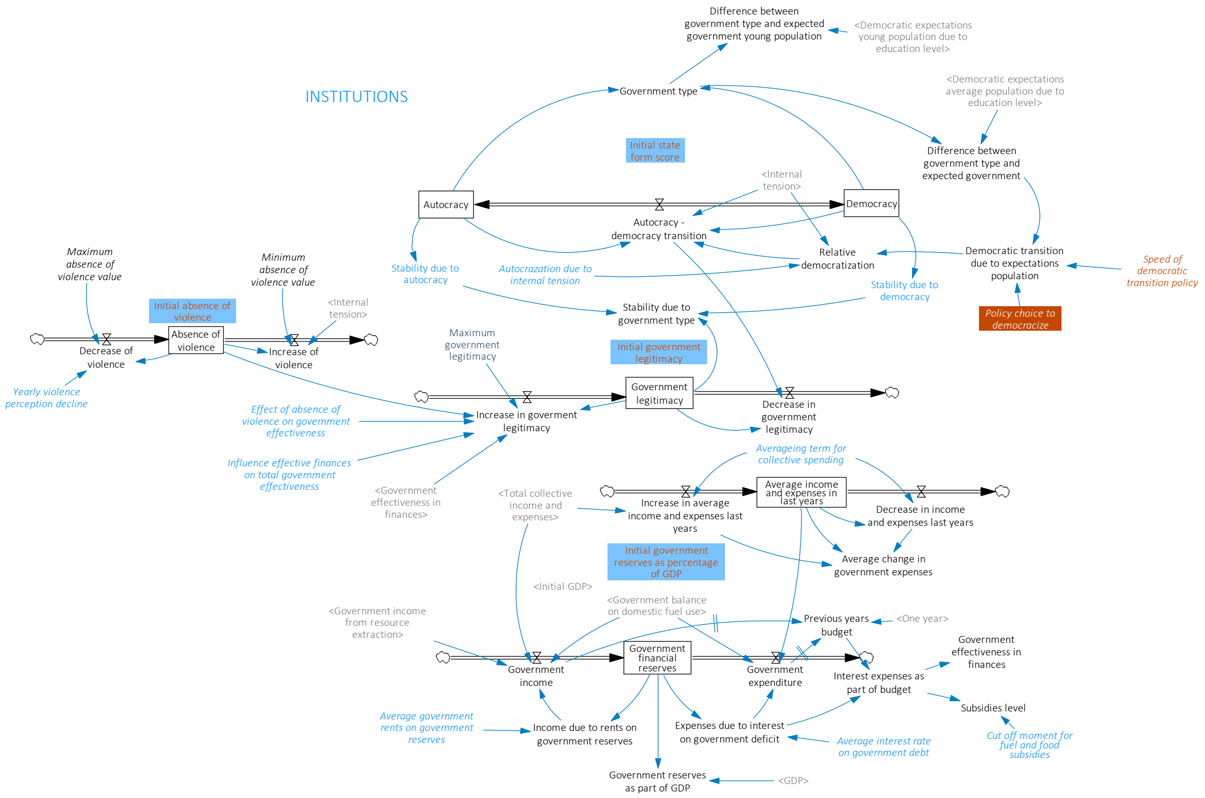

Figure 14. View of the institutions sub-model

2.5 Model validation

As usual in the field of SD, we approach model validity as whether the models were fit for purpose (Oreskes, Shrader-Frechette, and Belitz 1994, Sterman 2000, Lane 1995). In this case, the models had distinct uses. The global energy model was aimed as price scenario generator, where most emphasis was on scenarios outside the bandwidth of more conventional oil and gas price forecasts, like the forecasts of the EIA (2012) or BP (2013). In the country stability model, the purpose was to be able to assess whether certain price scenarios would positively or negatively affect country stability.

The model validity tests we performed can be split in approaches during the building of the model, and after completing it. Ex-ante, we assured validity by literature research, expert meetings, and unit checks on model equations. It is important to notice here, that the use of SD assumes system continuity, the importance of accumulation in the system, and causal relations between system elements. Literature about resources and resource scarcity intrinsically fits these assumptions very well. As a consequence, we were able to largely follow, or easily interpret, available literature about resource scarcity. However, the literature on state stability largely followed different paradigms, making model specification more difficult and model resemblance of the used literature less direct.

After finishing the first rounds of modelling, we applied checks on units and equations in the models, and performed modelling workshops with experts. These led to the conclusion that the models were fit for purpose.

3 Oil and gas prices selection

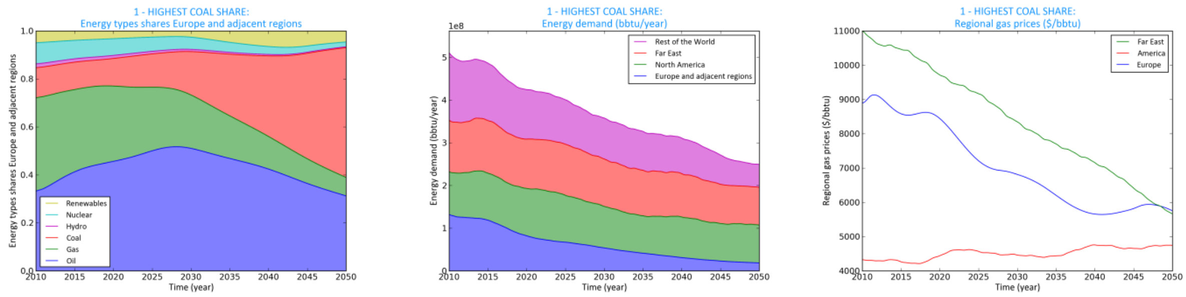

Figure 15. The global energy mix development (*left*), regional energy shares (*middle*), and regional gas prices (*right*) for the first scenario, which had the highest relative coal share found in the scenario set.

For the scenario selection, we applied two different metrics. The first metric looks at situations in which an individual energy type would have its largest share over all runs generated with the global energy model. In the second metric, we selected those models with most volatility. This last metric made use of a roughness measure [ref by one of authors] calculating the length of the curve composing the price development. We selected the five scenarios with the highest roughness.

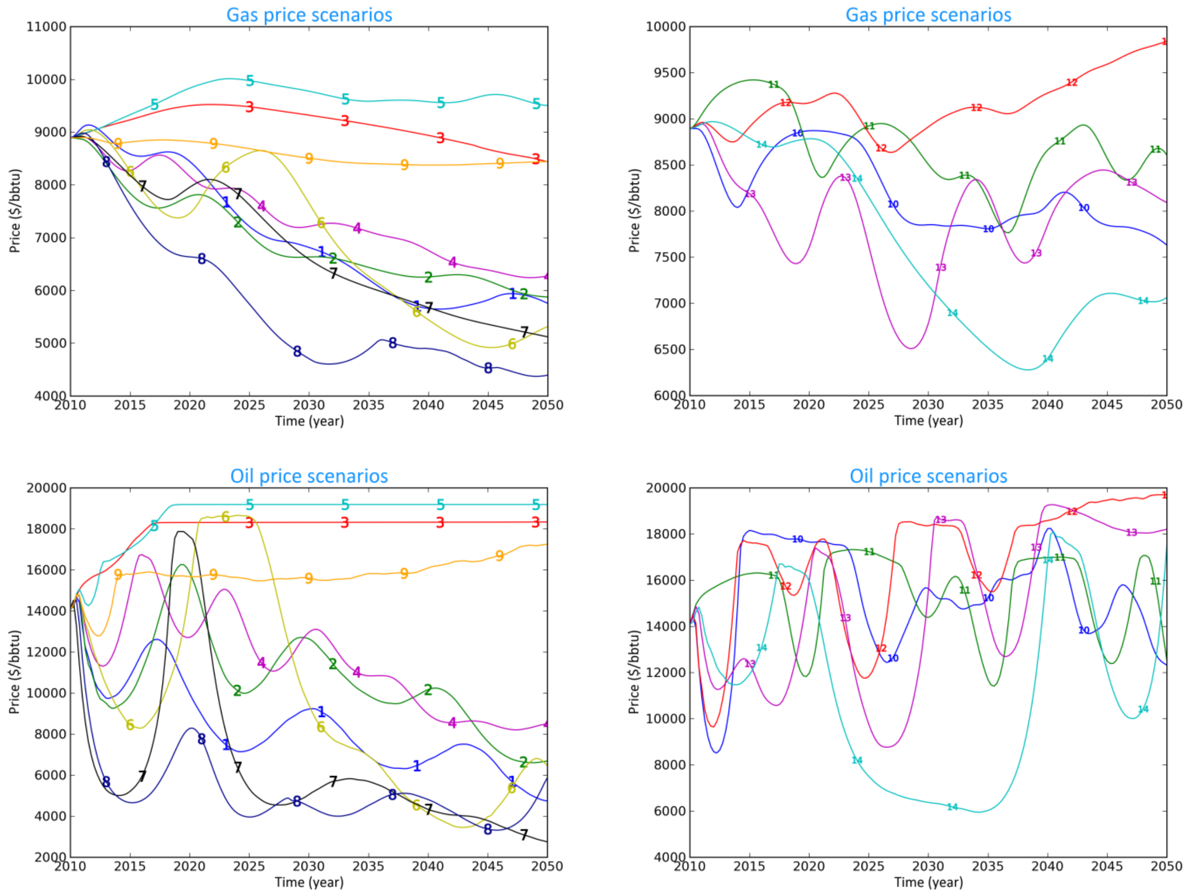

Figure 16. The gas and oil price scenarios as used in the shale gas study. Scenarios 1 to 9 were based on having a highest relative share of one (found in this study) of particular energy sources, where scenarios 10 to 14 were selected for their volatility.

One scenario is visible in Figure 15. This shows the situation with highest coal share in 2050. In each scenario, developments of the relative energy mix, demand shares in each region, and gas and oil prices are combined in generating an internally consistent narrative. These allow assessing under what circumstances certain price developments take place. The price scenarios eventually selected by this process are visible in Figure 16.

The volatility of the prices can be explained by looking carefully at the structure of the energy system. First, it is clear that the oil price is more volatile than the European gas price scenarios. This is motived by the fact that the European gas price is more or less a weighted average of all other major energy prices. Another explanation is the difference in market structure. Gas availability is primarily determined by either local resources, or the availability of infrastructure. Hence, gas is a commodity being sold as a capacity. Accumulation of this capacity is very difficult, as gas storage is difficult and prone to losses. In contrast, with oil trade, oil is made available in barrels, making available oil a stock quantity. Therefore, with oil accumulation of over production is possible, leading to significantly higher volatility of oil prices.

Second, with regard to this volatility it is clear that delays in the system play an important role in generating temporarily price plateaus, situations in which, for example, production does not meet theoretic demand. In such a case, prices are constantly high, but new capacity is being developed. After the development period, relatively much new capacity will become available, while substitution and reduction effects were also building up in strength. This situation will then lead to a collapse in prices after a prolonged period with relatively stable, high prices. The shale gas revolution can thus be seen as such a development, fitting into the normal hog cycle (Sterman 2000, 791, Meadows 1969) of energy commodities.

Third, by the analysis of the total set of price scenarios, it became clear that decoupling (*i.e.*, reduction of the energy intensity of GDP) is a very important factor in explaining lower energy prices. As decoupling causes the demand for all primary energy commodities to drop, it will affect all commodity prices. The consequence is that conventional energy sources will reach lower price levels, while renewable energy sources will have more problems in becoming accepted. Increased energy efficiency is thus counteracting of the energy transition.

4 Results for state stability

In Figure 17, we compared the influence of the selected scenarios from Figure 16 and two IEA scenarios with either constantly growing or declining price scenarios, with the ‘business as usual’ scenario of the IEA, which showed a constant price (2012). The assessment was thus mostly qualitative, where we looked for all time steps in any of the 100 scenarios generated per country whether a scenario caused more or less social unrest compared to the reference case. In the desirable cases, all time steps showed less instability; in the mostly desirable cases the average effect was less instability, but at some moments the country was more instable. For mostly undesirable and undesirable cases, the opposite was true. The fact that only mostly undesirable and mostly desirable cases were seen, even with regard to the moderate decreasing and moderate increasing price scenarios, is a consequence of the complexity of the system, with several counteracting feedback loops.

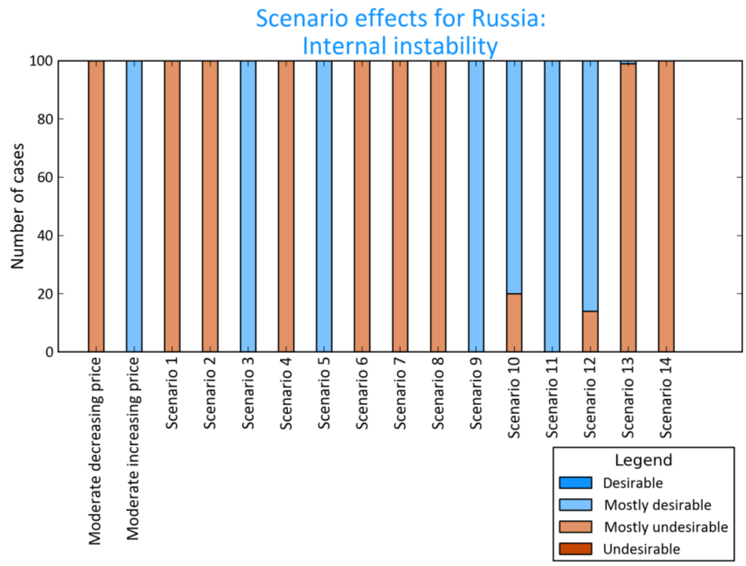

Figure 17. Scenario effects representation from the country stability model

Further assessment of the different consequences of the price scenarios gave the following insights. First, as instability is a self-reinforcing effect, price scenarios with early drops in the prices show higher instability throughout the runs. In these situations, lower prices caused increased (youth) unemployment leading to discontent and eventually increased instability. This effect was strengthened especially when a worsened governmental financial situation asked for slashing of food and fuel subsidies, creating an immediate decrease in purchasing power. When the instability limits economic recovery, this is a difficult situation to resolve for a country.

Second, it became clear that buffers were essential in avoiding increased instability. Important buffers are sovereign wealth funds and labour migrants. The first is quite clear: in the case of a recession, financial buffers allow government to continue spending without risking having to slash food and fuel subsidies. The second is often used by autocratic regimes trying to avoid increased unemployment of the original population. In these cases, labour migrants are a buffer that can be disposed of in case of a worsened economic situation, postponing a dangerous situation with high levels of (youth) unemployment.

Finally, the correlational effects of the regime type and stability are very important (Marshall and Cole 2011). Regime types generally follow population expectations with a delay. The transition between a autocracy and a democracy is an unstable period. Research by the Center for Systemic Peace has shown that these transitional democracies, or ‘anocracies’ are 5 times more unstable than autocracies and 10 times more unstable than democracies.

Of the countries considered in this study, being Algeria, Azerbaijan, Egypt, Kazakhstan, Qatar, Russia, and Saudi Arabia, especially Russia and Algeria are most at risk for instability in periods with low energy prices. As most countries in our study, they generate most resource rents from the more price volatile oil resources. Further, both countries have only limited buffers and an inherently unstable regime type.

5 Discussion and conclusions

In this paper, we have presented two SD models, where the first model simulated the global energy system, and the second model country stability. We used these models to assess the potential impact of the US’ shale gas revolution on state stability in traditional oil and gas exporting countries in the vicinity of Europe.

The approach we used in this study, using a global energy model to produce scenarios which functioned as input for ‘stress testing’ of countries on the effects on their stability, proved very useful. It allowed to determine which drivers caused, indirectly, heightened instability in countries necessary of European energy policy.

The approach can be expended in several ways. First, we could make more use of computerised learning algorithms, like the Patient Rule Induction Method (PRIM), to select the input variables which, alone or in combination, often lead to either increase instability or the lowering of prices. Second, the country analysis could be expended with countries outside the direct vicinity of Europe, like Venezuela. Third, another promising direction for further research would be closing the loop by feeding the extraction capacity from the country stability model back to the global energy model. Fourth, labour migrants may form a buffer in safeguarding country stability, but may also cause grievances which have currently been left outside the scope of this research.

Regarding the energy part of the case, the following conclusions can be drawn. First, the oil price is structurally more volatile than the gas price. Therefore, a situation in which (shale) gas partly replaces oil, for instance as feedstock in chemical plants, may lead to a larger decline in income than purely a lower gas price could possible create. Second, shale gas fits in the normal hog cycle of energy commodities, increasing the plausibility of shale gas being part of developments leading to periods with considerably lower energy prices. Third, the effects of decoupling energy demand and GDP on energy prices are easily much larger than the effects caused by shale gas, as decoupling leads to an overall decline in demand (growth).

Regarding state stability, it can first be concluded that the case where shale gas and other unconventional energy sources lead to lower oil prices would have most undesirable effects on traditional oil and gas exporting countries, as these countries practically all generate most resource rents by oil. In these cases, a reduction in resource rents by lower oil prices may lead to increased youth unemployment and, when subsidies need to be cut, worsened purchasing power. Second, as social unrest has a negative effect on economic development, avoiding unrest is most desirable. Third, countries with limited sovereign wealth funds as part of GDP or labour immigrants, are more vulnerable, as they lack buffer capacity for (temporarily) avoiding social unrest caused by economic downturn. Fourth, regime type is also very important for the stability of a country, as countries transitioning from an autocratic regime type to a democratic regime type are more unstable than either full autocracies or full democracies. Taking these four points into account and by careful deliberation over our model results, we were able to conclude that especially Algeria and Russia are at risk for these developments.

Finally, the insights generated with the country stability model especially make clear which economic vulnerabilities countries have. In the long run, increased instability in the neighbourhood of Europe is an undesirable effect. However, as the present crisis in Ukraine demonstrates, these insights may be useful in determining which economic sanctions would harm countries like Russia most. Hence, the model insights proved to be more extensive than could have been expected in advance.

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