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Globalisation of natural gas markets – effects on prices and trade patterns

Abstract:
The regional natural gas markets are expected to gradually become more integrated. The major driving forces are lower LNG costs, more spot trade, and increased need for imports into the US and other key markets. In this paper we examine various scenarios for a future global gas market, particularly focusing on natural gas prices and trade patterns. We use a numerical model of the international energy markets, with detailed modelling of regional gas production and international gas transport. Scenarios with different assumptions about future demand and supply conditions are simulated. Our results suggest that trade between continents will grow considerably over the next couple of decades, and that prices in the main import regions will remain around current levels. However, significant constraints on exports from the Middle East may alter this picture.

Keywords: Natural gas trade, gas prices, numerical model

JEL classification: C61, F17, L95, Q31

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1. Introduction

The natural gas markets in different regions are gradually becoming more integrated. This globalisation process is due to several reasons. First, the costs of transport (especially LNG – Liquefied Natural Gas) have fallen significantly over the last 1-2 decades (except for the last few years), and constitute a much lower share of the wholesale price of gas than 15-20 years ago (Brito and Hartley, 2007). Second, gas reserves in the main consuming areas are gradually reduced compared with annual consumption,[1] which implies an upward pressure on domestic prices and increased imports of gas. With a larger share of gas reserves located in a few geographical locations such as Russia and the Middle East, intercontinental trade becomes more profitable. Third, an increase in the share of spot trade means that short-term price differences between regions may be more easily exploited by re-routing the gas (especially LNG), cf. IEA (2006).

In this paper we look into future scenarios for a globalised natural gas market. Using a detailed numerical partial equilibrium model of the international gas, oil and coal markets, we explore how regional gas prices and trade patterns may develop until 2030 under different scenarios about future market conditions. Not surprisingly, we find that intercontinental trade will grow considerably over the next decades, reducing the upward pressure on gas prices in import regions such as Europe and North America. This result depends crucially, however, on the absence of constraints in the expansion of the gas industry in the Middle East. If the growth in gas production from this region is suppressed, we may see quite higher prices from 2020 onwards, and less intercontinental trade.

Our numerical analysis builds on the assumption that the international gas markets are liberalised and integrated. This is in contrast with the results in Siliverstovs et al. (2005), who find no sign of price integration between the North American market and the European/Japanese markets in the period 1994-2003. Their findings may reflect that the gas markets in continental Europe and North-East Asia are not yet fully liberalised. On the other hand, the gas markets in North America and the UK have been liberalised for more than a decade, with prices linked to liquid spot markets, and Neumann (2007) finds increasing convergence of spot prices in the US and the UK based on data for 1999-2007. Moreover, the EU has adopted two directives on gas liberalisation over the last decade (EU, 1998, 2003), although the speed of implementation has been quite slow. With rapid growth in international spot trade, gas suppliers may find it easier to sell their gas in new markets, especially in the short term. Jensen (2004) claims that a moderate level of spot trade may be sufficient to balance the regional

[1] In the EU, the ratio has fallen from 9 to 6 years since the year 2000 (BP, 2008).

markets. Thus, we believe that the international gas markets are heading towards a globalised market, although with region-specific prices.

Whereas gas consumption in OECD regions has grown slowly over the last decade, consumption outside OECD and the former Soviet Union has increased by more than 5 per cent annually since mid 1990's (BP, 2008). In China, gas consumption more than tripled from 1997 to 2007. A similar picture is seen on the supply side, where gas production in the OECD has been rather constant since the turn of the century. On the other hand, production both in the Middle East and in Africa has more or less doubled over the last decade. Although intercontinental trade has been modest so far, some arbitrage trading has occurred in the Atlantic Basin, and the Middle East has to some extent become a swing supplier to both South and East Asia and the Atlantic Basin. So far, most of the LNG from the Middle East has been shipped eastwards, to India, Japan and South Korea, and only about 15 per cent to the Atlantic Basin (BP, 2008).

Besides the studies presented in EMF (2007) (and in this special issue), there have been few previous numerical analyses of globalised natural gas markets. One exception is Rosendahl and Sagen (2007), who examine the effects of transport cost reductions on gas prices in different regions (using the same model as in this paper). They show that gas prices in some import regions may increase when transport costs decline, e.g., because of different choice of transport mode or because of different transport distances between trading regions. Numerical analyses of the European gas market are found in Golombek et al. (1998), Boots et al. (2004) and Egging and Gabriel (2006), whereas MacAvoy and Moshkin (2000) and Gabriel et al. (2005) simulate the North American gas market.

In the following section we briefly describe the numerical model FRISBEE. Then we go on to present the simulation results of future scenarios in Section 3. Finally we conclude.

2. Model description

We use a numerical model of the international energy markets called FRISBEE.[2] It is a recursively dynamic partial equilibrium model with 13 global regions, cf. Table 1. Supply and demand of fossil fuels and electricity are modelled in each region. FRISBEE accounts for discoveries, reserves, field development and production of oil and natural gas, distributed on regions and field groups. Supply of coal and electricity are modelled in less detail. There are three demand sectors in the model:

[2] See Aune et al. (2005) for a more extensive presentation of the FRISBEE model. Aune et al. focus on the oil market, but natural gas supply (and demand) is modelled quite similarly as oil supply, so most of the model description carries over. Rosendahl and Sagen (2007) also provide a (more brief) description of the gas market modelling.

'Manufacturing industries', 'Power generation', and 'Others' (including households). All markets clear each year, and annual, regional supply, demand, prices and trade flows are among the outputs of the model. Seasonal variations in demand and supply are not included in FRISBEE, which means that variations in e.g. trade directions over the year are not captured by the model. The base year of the model is 2000, and it is programmed in GAMS (Brooke et al., 2005).

Table 1. Regions in the FRISBEE model

Industrialised regions	*Regions in transition*	*Developing regions*
Canada (CAN)	Caspian region (CAR)	Africa (AFR)
OECD Pacific (OEP)	Eastern Europe (EEU)	China (CHI)
USA	Russia/Ukraine/Belarus (RUB)	Latin America (LAM)
Western Europe (WEU)		OPEC-Middle East (OPM)
		Rest-Asia (RAS)
		OPEC-Africa (OPA)

Natural gas demand is a function of the end-user prices of all energy goods. The own price elasticities for 'Manufacturing industries' and 'Others' are on average around -0.3 in the long run (around -0.1 in the short run). Cross-price elasticities are in general small. In the long run, gas demand is particularly dependent on income growth – (per capita) income elasticities are on average around 0.6. The elasticity of population is set equal to one. Finally, a moderate, exogenous energy efficiency rate is assumed (0.25% p.a. within OECD and 0.5% p.a. outside OECD). Fuel demand in the 'Power generation' sector is driven by existing capacities and generation costs (including fuel prices) for different technologies, as well as the electricity price. Substitution possibilities are thus much higher in the power sector than in the two end-user sectors.

Traditionally, the natural gas markets in Europe and to some degree Asia-Pacific have been dominated by only a few large players, both upstream and downstream, and the markets have been highly regulated. As the gas markets become more integrated, the potential for upstream market power diminishes.[3] Moreover, liberalisation processes are taking place both in OECD and non-OECD regions (IEA, 2006), and this is gradually reducing the market power of large, downstream companies. The extent of spot trade is growing fast, and gas price indexation is partially replacing the oil price link in long-term contracts (Cornot-Gandolphe, 2005).[4] Consequently, although it might be seen as a

[3] Gas exports from Russia (the world's largest gas holder and exporter) constitute only 5 per cent of global production (BP, 2008), and there are concerns about Russia's ability to stabilize its future export volumes (Sagen and Tsygankova, 2008). The potential for market power increases if several countries form a cartel, which is one of the alternative scenarios we consider.

[4] Although there is no formal link between oil and gas prices in the model, prices of fossil fuels (and electricity) are partially connected through the (small) cross-price elasticities, and through the competition between different power technologies (cf. Hartley et al., 2008).

simplification of the current market structure, in our future scenarios for the global natural gas markets we assume fully competitive and liberalised markets.

FRISBEE distinguishes between (oil and gas) fields in production, undeveloped fields and undiscovered fields. Data on field characteristics are based on an extensive database of global petroleum reserves in the year 2000, and data on production costs are based on the same source. Supply from developed fields in the model is set so that marginal operating costs equal producer prices net of gross taxes. Operating costs are increasing functions of production, but are generally low unless production is close to the fields' production capacity; then they increase rapidly. The cost functions are calibrated based on data on production costs in different locations.

Oil and gas companies may invest in new fields and in reserve extensions of developed fields. Investments decisions are driven by expected net present values (NPV), which are calculated for four field categories in each of the 13 regions.[5] Expected NPV depends on expected prices (adaptive), a pre-specified required rate of return (set to 10 per cent in real terms), unit operating and capital costs, and net and gross tax rates. Unit capital costs are convex in the short term, and increase when the pool of undeveloped reserves declines (for new fields), and when the recovery rate rises (for reserve extension).

New discoveries are modelled in a simpler way. The amount of discoveries depends on expected prices and expected undiscovered reserves in each region (USGS, 2000).

All arbitrage opportunities are assumed to be exploited in the model, so that price differences between two regions never exceed the corresponding transport costs. Unit costs of LNG and pipelines are assumed to be constant in this analysis. Both capital and operating costs are included in the cost figures, except for pipeline capacities existing before 2007 (where only operating costs matter). Total transportation costs are linear functions of the distance between the regions. No geopolitical or other constraints are restricting investments in new transportation capacity in the model. Each year the cheapest transport technology between a pair of regions is chosen (i.e., LNG or pipeline). Thus, a region may import both via LNG and pipeline transport, but not from the same region. Data on transport costs are mainly based on OME (2001).

[5] Classification of categories differs across regions, e.g. according to onshore vs. offshore, deep vs. shallow water, field size.

3. Future scenarios for a globalised gas market

In this section we present different scenarios for a globalised natural gas market towards 2030. Obviously, there are many uncertainties about how this market will evolve, not only to what degree the regional markets will be integrated. Thus, the quantitative results should be interpreted with caution. Perhaps most interesting is the comparison between scenarios, which will demonstrate the effects of some potentially important driving forces. Table 2 provides a brief overview of the different scenarios.

Table 2. Overview of scenarios

Scenarios	***Key assumptions***
Reference Scenario	Based on EMF (2007) and EIA (2006)
High Demand Scenario	GDP annual growth rate increased by 0.5%
Constrained Export Scenario	Exports from Russia and OPEC-Middle East constrained at 2005 levels + volumes under construction
Middle East Cartel Scenario	Exports from OPEC-Middle East are set so as to maximise export revenues from this region

Reference Scenario

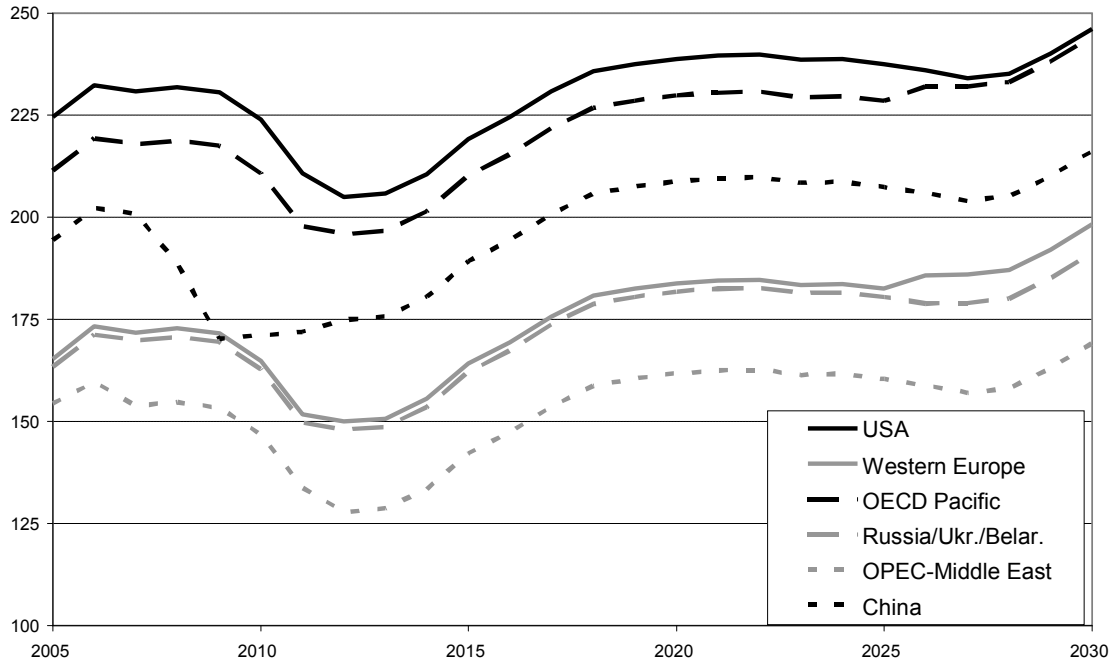
The Reference Scenario assumes a rather constant real oil price between $50 and $60 per barrel,[6] and an annual average growth in world real GDP of 3.8 per cent (growth rates vary between regions). The global gas market is assumed to behave competitively, without any constraints in production, transport or distribution of gas. Costs of producing gas from a specific field are exogenously reduced over time (0.5-1.5 per cent p.a.), but unit costs may still rise because the cheapest fields are extracted first. Transport costs are held constant (in real terms) at 2003 levels. Even though costs of LNG have declined considerably since the beginning of the 1990's, costs have increased lately, and it is hard to know whether further technological progress may push the unit costs further down in years to come. Energy and environmental policies are fixed at their base year levels, which mean that we disregard any effects from the Kyoto protocol and any future climate agreements on the gas market. Policies to reduce CO_2-emissions vary a lot, and may in general have ambiguous effects on gas demand, so it is difficult to say how this could have affected the numerical results. Although we refer to this scenario as the Reference Scenario, it is not necessarily the most realistic one (more like a benchmark scenario).

[6] This may seem quite low compared to recent oil price levels. However, as there are no formal links between oil and gas prices in the model, the oil price has little influence on the gas market (despite some substitution between oil and gas among end-users).

Figure 1 shows how the wellhead prices develop in selected regions up to 2030 in the Reference Scenario. We notice that the prices increase modestly in all regions in the second half of this time period, but prices in 2030 are only 10-20 per cent higher than in 2005 (in real terms). This result reflects that there are sufficient gas reserves in the world (at affordable costs) to meet the expected demand growth over the next couple of decades. However, as the cheapest reserves are extracted first within each region, the prices of natural gas will tend to rise further into the future (despite new discoveries and moderate technological progress).[7]

The figure further shows that the price differentials between regions are rather constant through time. The explanation for this is that the price differential between a pair of trading regions is equal to the unit costs of transport between these two regions, and these costs are assumed to be constant in the Reference Scenario. Import regions that are far away (in terms of transport costs) from key export regions will typically face higher prices than import regions that are closer. That's why prices in the US and OECD Pacific are higher than in Europe.

Figure 1. Wellhead gas prices in selected regions in the Reference Scenario. 2000 US$/toe



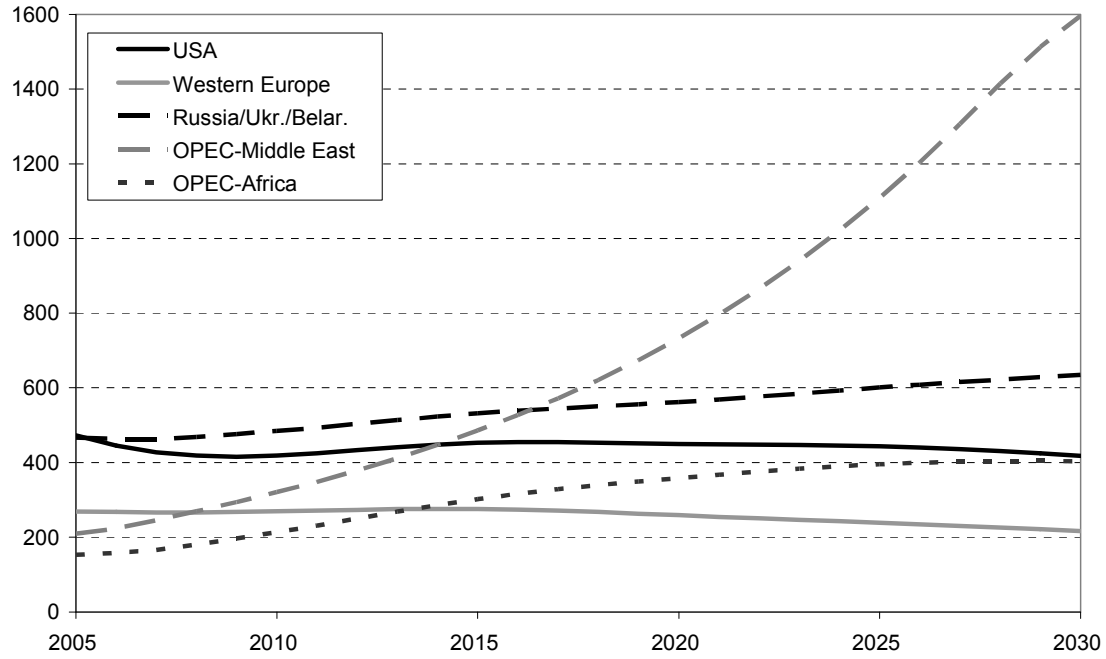
Figures 2-3 show the development in gas production and consumption in selected regions in the Reference Scenario. The most striking result in Figure 2 is the dramatic increase in gas production in

[7] Significantly more new discoveries or more rapid technological progress in energy production (either for gas or for close substitutes) may counteract this upward pressure on the gas price (which is due to gas being a non-renewable resource).

OPEC-Middle East. Annual growth from 2005 to 2030 is 8-9 per cent, which is due to a very large resource base combined with relatively low production costs. Although actual growth since 2000 has been in the same range (BP, 2008), it may be questioned whether such high growth rates are sustainable for 2-3 decades. Thus, two of the alternative scenarios we consider assume lower growth rates (either explicitly or implicitly). Production in OPEC-Africa also grows considerably, especially in the first half of this period, but the growth potential is much more limited than in the Middle East. Russia, which holds a quarter of the global gas reserves, also increases its production, but only modestly due to high production costs compared with e.g. the Middle East.

Another interesting observation from Figure 2 is that gas production in the US and Western Europe is only modestly reduced up to 2030 (by 12 and 19 per cent from 2005, respectively). This is particularly interesting as the R/P-ratio (reserve over production) in the US was only 11 years at the end of 2007 (BP, 2008). Remaining reserves in the US have actually increased each year since 1998 according to BP. This is mainly due to upgrading of non-conventional gas resources, which counteracts the more significant reduction in conventional gas production. The future growth in non-conventional gas extraction in the US will have significant bearings on global trade patterns in the coming decades. Lower than predicted growth potential could lead to much more imports of LNG, whereas higher than predicted growth rates could make North America self sufficient for a longer period of time.

Figure 2. Production of gas in selected regions in the Reference Scenario. Mtoe/year



Consumption of natural gas increases in all regions in the Reference Scenario, but there are significant regional differences (see Figures 3a and 3b). Among OECD regions, consumption grows much stronger in Europe (and Canada due to tar sand production) than in the US and OECD Pacific. This may be explained by consistently lower prices in Europe than in the other OECD regions (cf. Figure 1), which makes gas power more competitive (especially compared to coal) in Europe than in the US and Japan.

The strongest growth in gas consumption is clearly seen outside OECD, particularly in China where consumption more than quadruples from 2005 to 2030 (though from a rather modest level). Other parts of Asia, Latin America and Africa also experience high growth rates. Gas demand in Russia grows faster than in OECD regions, but slower than outside OECD. We have assumed that Russian end-user prices are gradually increased in line with official governmental plans, and this dampens the demand growth somewhat.

Figure 3a. Consumption of gas in selected regions in the Reference Scenario. Mtoe/year

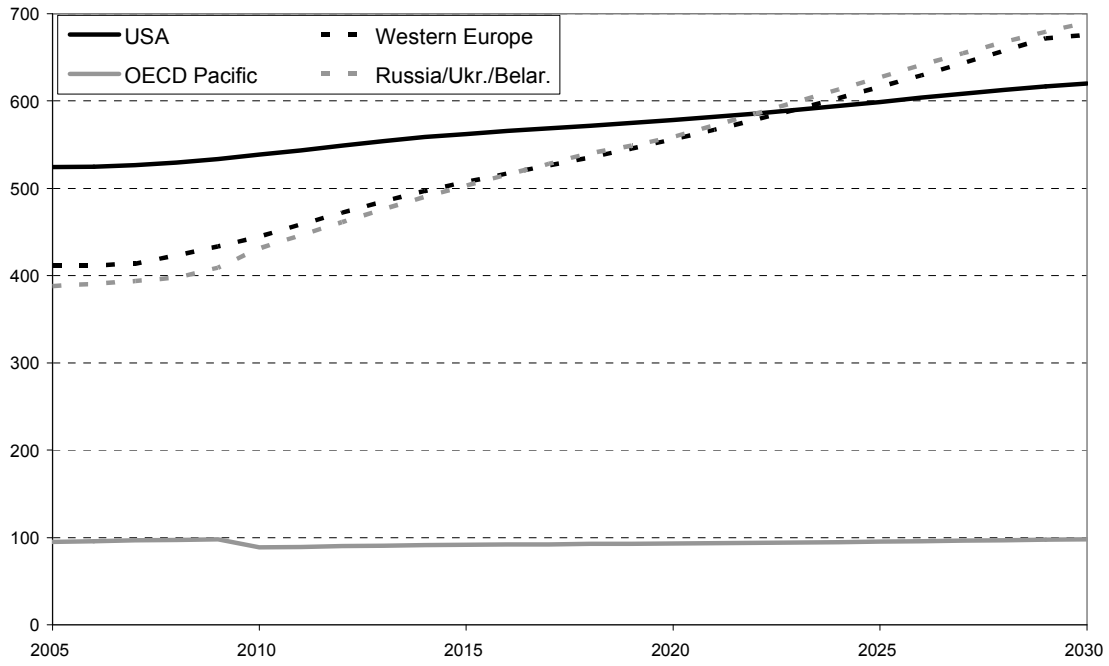
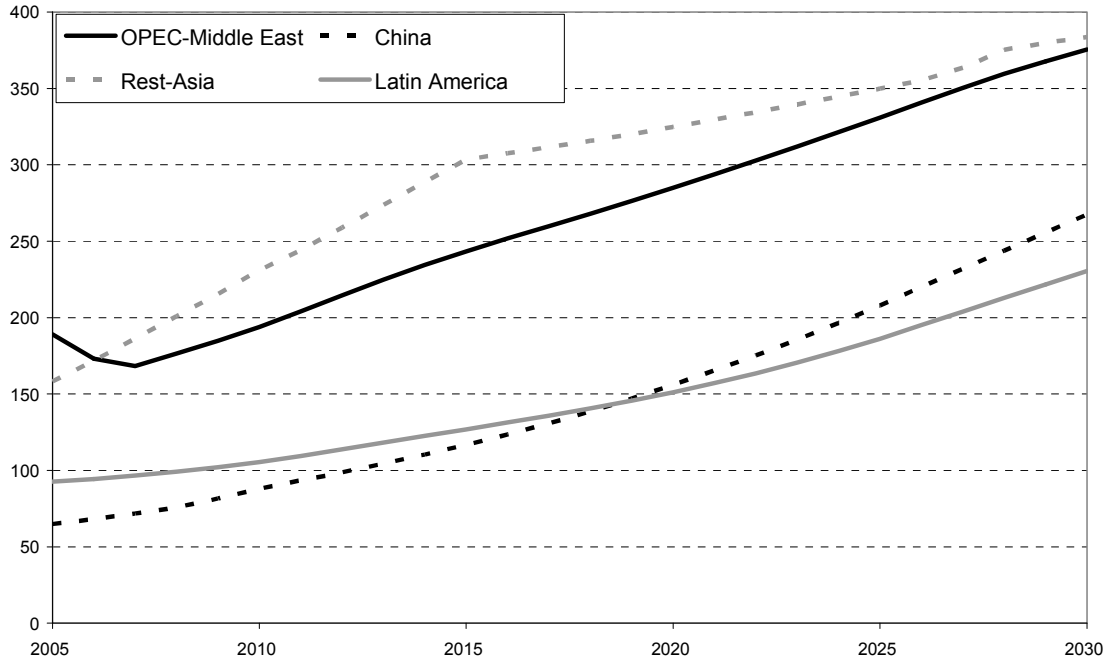


Figure 3b. Consumption of gas in selected regions in the Reference Scenario. Mtoe/year



In the Reference Scenario, there is a gradual increase in transatlantic trade over the time horizon. In 2020 annual trade over the Atlantic is 114 Mtoe per year, and this increases to 325 Mtoe per year in 2030. The volumes of trade depend highly on the assumptions about costs of LNG. As costs of liquefaction have risen significantly since 2003 (i.e., our benchmark for transport costs), the Reference Scenario may overestimate the development in transatlantic trade.[8] On the other hand, FRISBEE only models annual prices and volumes, and thus short-term arbitrage options are not taken into account.

Alternative Scenarios

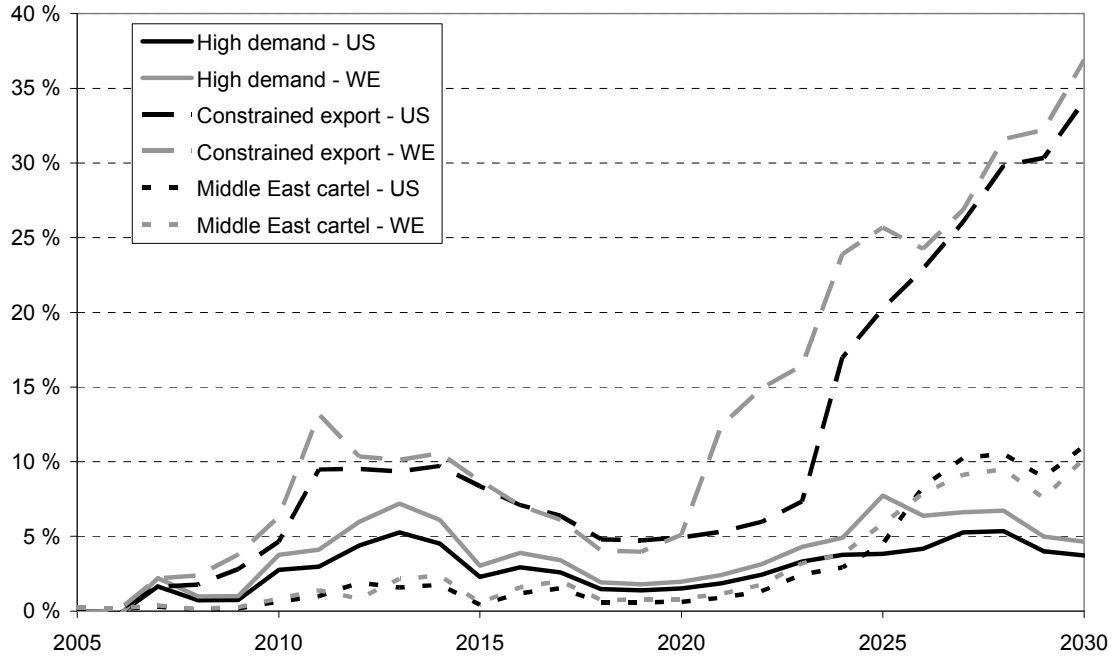
In this subsection we focus on three potentially important driving forces for the international gas markets. These are economic growth, supply constraints and market power (see Table 2). We want to examine to what degree these factors may influence the outcome of the gas market.

Figure 4 shows how gas prices in the US and Western Europe are changed in the three alternative scenarios (compared with the Reference Scenario). As expected the prices increase in all scenarios, either because of higher growth in demand or because of reduced gas supply. In particular, a constraint on exports from the Middle East and Russia at current levels (including volumes under construction) leads to significantly higher prices after 2020. This is not surprising, given the production growth in

[8] Rosendahl and Sagen (2007) look into the effects on prices and transatlantic trade of different assumption about costs of LNG and pipelines.

OPEC-Middle East in the Reference Scenario (see Figure 2). However, such a constraint seems rather pessimistic, unless there is a significant change in the (geo)political situation in the Middle East.

Figure 4. Percentage changes in gas prices in selected regions in alternative scenarios (compared to Reference Scenario)



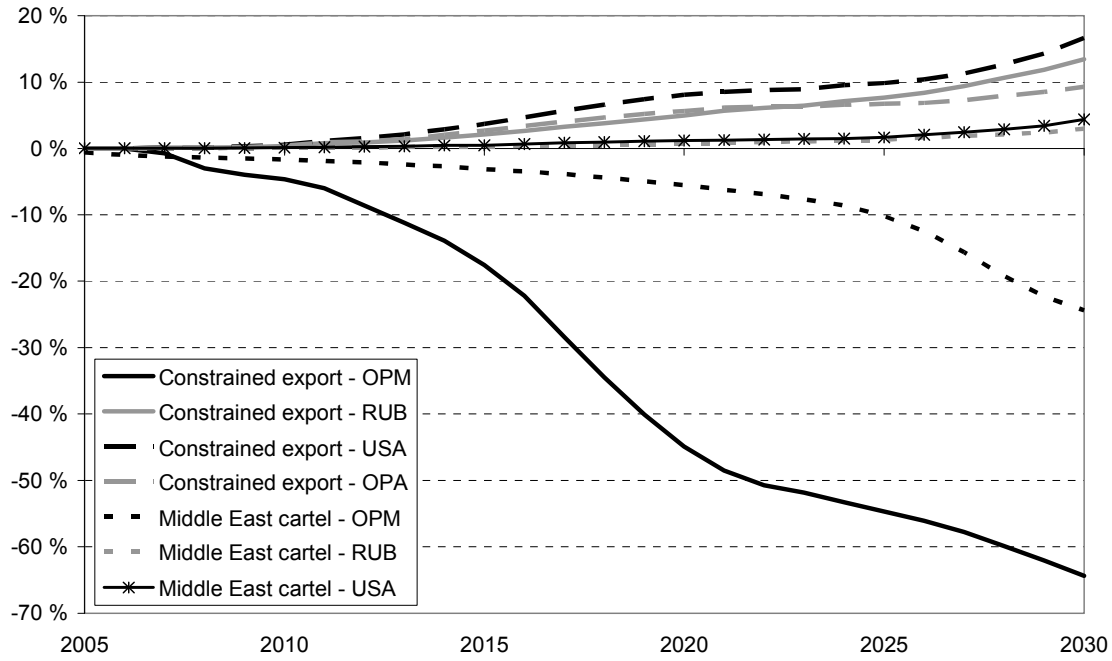
On the other hand, cartel behaviour by the OPEC countries in the Middle East has only small effects on the gas prices, at least until 2020.[9] The reason is that OPEC-Middle East reduces its supply (and export) only moderately in the Middle East Cartel Scenario; cf. Figure 5. This indicates that there is limited potential for market power in a fully integrated global gas market, unless a larger group of countries joins the Middle East in this respect (e.g., Russia or OPEC countries in Africa). In a less integrated global market, however, OPEC-Middle East may find it more profitable to cut back on supply in order to push prices upwards in some import regions.

As seen in Figure 5, Russia actually increases production in the Constrained Export Scenario, even though its export is constrained at current levels. The explanation is simply that Russia's export is gradually falling in the Reference Scenario, as growth in domestic demand outpaces its supply growth. This is in line with previous studies by e.g. Sagen and Tsygankova (2008). When exports from OPEC-Middle East are constrained, prices in import regions increase, and thus Russia finds it profitable to increase its export. We further see that production in other regions such as OPEC-Africa and the US

[9] In the Middle East Cartel Scenario OPEC-Middle East introduces a fixed export duty so as to maximize the sum of producer surplus (including export revenues), domestic consumer surplus and government income.

increase in this scenario. US production rises by more than 10 per cent after 2025, which means that the US import share of gas in 2030 is reduced from one third in the Reference Scenario to only 4 per cent in the Constrained Export Scenario. In Western Europe the corresponding import share is reduced from two thirds to about 50 per cent.

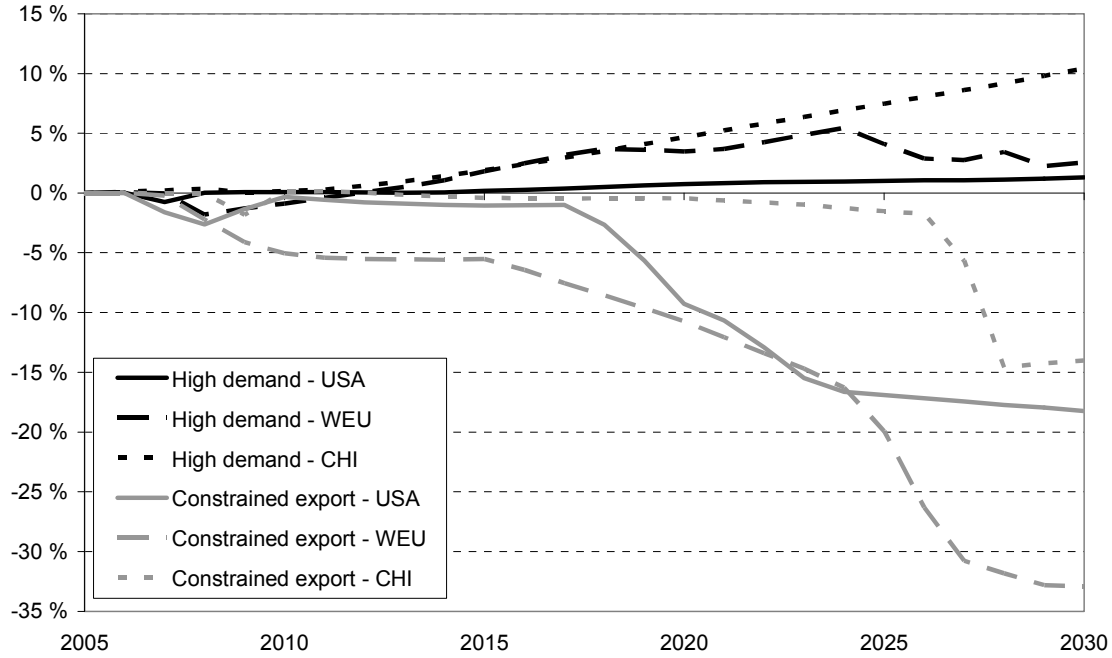
Figure 5. Percentage changes in gas production in selected regions in alternative scenarios (compared to the Reference Scenario)[*]



[*] OPM: OPEC-Middle East; RUB: Russia/Ukraine/Belarus; OPA: OPEC-Africa

The reduced import share in the Constrained Export Scenario is not only due to increased domestic production, but also to reduced consumption, cf. Figure 6. In particular, with higher prices as a result of constrained supply from the Middle East, natural gas loses significant market shares in the regional power markets. Both in the US, Western Europe and China the *growth* in gas power production is reduced, and eventually the level of production starts to fall, too. Coal power production increases correspondingly.

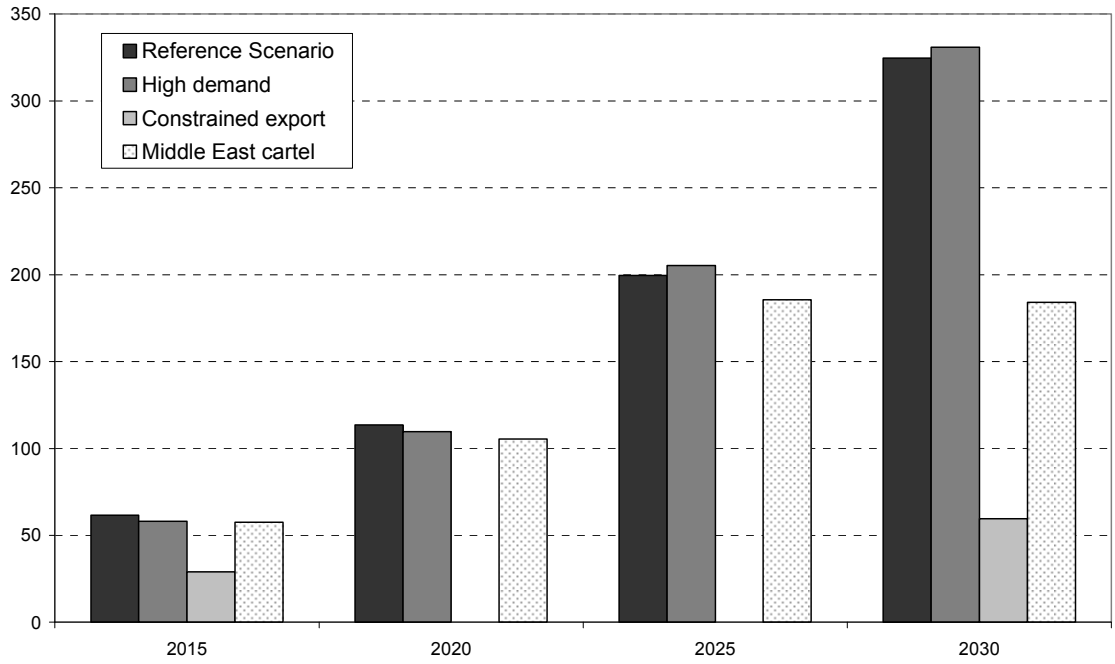
Figure 6. Percentage changes in gas consumption in selected regions in alternative scenarios (compared to Reference Scenario)



In contrast, in the High Demand Scenario, with higher GDP growth, natural gas demand grows faster, particularly in China. Demand growth in OECD regions is only moderately increased. Although global GDP in 2030 is 13 per cent higher than in the Reference Scenario, global consumption of natural gas is merely 3 per cent higher. The increased prices of gas are the main explanation for this modest effect.

Gas trade across the Atlantic Ocean develops quite differently in the various scenarios, see Figure 7. In the Reference Scenario there is a significant growth, particularly after 2015 when production in OPEC-Middle East gets very large. Transatlantic trade in the High Demand Scenario is almost similar to the Reference Scenario, as most of the demand growth takes place in Asia. On the other hand, in the Constrained Export Scenario there is little or no trade across the Atlantic as increased prices in North America stimulates own production and more imports from Latin America. Eventually, however, imports from across the Atlantic Ocean are needed to balance the American market despite high prices also in Eurasia. In the Middle East Cartel Scenario, there are small trade differences from the Reference Scenario until the end of our time horizon, which is consistent with the price and production changes observed in Figures 4 and 5.

Figure 7. Annual gas trade across the Atlantic Ocean (to North America) in different scenarios. Mtoe/year



The evolution of global LNG trade follows a similar pattern as transatlantic trade. In 2015 LNG trade between regions amounts to 4-5 per cent of global gas production. In the Reference and High demand scenarios this share grows to 8-9 per cent in 2030, versus 6 per cent in the two scenarios with some constraint on gas export from the Middle East. In addition to trade across the Atlantic, LNG is also shipped to some extent from Latin to North America, and between the Asian regions.

Conclusions

Globalisation of natural gas markets will substantially increase the level of intercontinental trade, and prices in different regions will become more integrated. Without significant constraints on exports from the Middle East, prices in import regions may remain around or just above current levels. These are the main results from our numerical simulations of the international gas markets.

The key to the future natural gas markets lies in the Middle East. We have seen that a constraint on the export of gas from this region at current levels (including volumes under construction) may lead to much higher prices of natural gas after 2020. Consumption of gas will grow considerably slower, particularly in the power market, leading the way for further increases in coal power production.

However, such a constraint on export is not profitable for the Middle Eastern gas producers. If they behave like a gas cartel, maximising their joint consumer and producer surplus (including export

revenues), they are more likely to choose a moderate reduction in their production growth. In this case, prices of gas are hardly increased until after 2020, when there is a moderate price increase compared to our Reference Scenario. Expanding the cartel to include other countries such as Russia or OPEC countries in Africa may increase its market power. However, we find that Russia's export is gradually declining, reducing its potential gains from any cartelisation.

There are several uncertainties about the future gas markets that are not analysed in this paper. We have already mentioned the costs of LNG, which will be determinant for the globalisation process. Another crucial factor is the international focus on climate change and energy security, which may lead to significant policy measures affecting the gas markets. When it comes to climate change, natural gas is a cleaner fuel than other fossil fuels, but obviously not as carbon-free as renewables and nuclear. Thus, a moderate climate policy may stimulate gas consumption, whereas a strong policy may have the opposite effect in the long run as carbon-free technologies make significant progress.

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