ABSTRACT

This paper analyses the welfare effects of two policies directed at the security of energy supply: investments in strategic petroleum reserves and a cap on the production of gas from the largest Dutch gas field. *Market failures can justify such policies, in particular failure of individual consumers to account for their impact on energy prices and import dependency and, hence, the vulnerability of a country to geopolitical conflicts. But as the costs of investing in strategic reserves and capping gas production are not negligible, these options are welfare enhancing only in specific circumstances. Generally, measures to improve the functioning of energy markets promise to achieve more than investment-intensive measures or those restricting options of profit-maximising agents. However, policy makers might find it politically expedient to adopt rather than reject inefficient security-of-supply policies.*

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The economics of promoting security of energy supply

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1. Introduction

The security of energy supply has become of increasing concern in recent years. In Europe, important factors contributing to this are the liberalisation of European energy markets and Europe's growing dependence on oil and gas imports from politically less stable countries. As for the debate about policies aimed at ensuring supply security, two different perspectives can be distinguished: a political and an economic one (see CPB 2006).

From a political viewpoint, ensuring security of supply often means that a stable supply of energy needs to be guaranteed at 'affordable' prices, regardless of the circumstances (see, for instance, European Commission 2000). The 2005 Directive on Security of Supply (European Commission 2005, Article 2) states: "security of electricity supply means the ability of an electricity system to supply final customers with electricity, (...) the satisfaction of foreseeable demands of consumers to use electricity without the need to enforce measures to reduce consumption." This definition reflects pre-liberalisation goals as it takes demand as an exogenous factor.[1]

From an economic viewpoint, however, the concept of security of supply is related to the efficiency of providing energy to consumers. Markets will always show variations in supply and demand and, hence, in prices. A reduction in supply puts upward pressure on prices, thereby curbing demand, and an increase in demand raises prices and thus encourages an increase in supply. From an economic perspective, the question of whether or not the degree of supply security is optimal can be rephrased as whether or not the market succeeds in achieving an efficient balancing of supply and demand in the short run and an efficient level of investment in the long run. Efficiency requires that short-run prices fluctuate to reflect changing supply and demand conditions and that market clearing may involve reduction of demand.

The two perspectives, therefore, lead to conflicting goals since from an economic point of view, supplying all demand is bound to be inefficient and prices will have to fluctuate to clear the markets. In this paper, we approach the issue of security of supply from the economic perspective. In Section 2, we explore how energy markets deal with risks and disturbances and we consider possible market failures that could justify government intervention. Section 3 and Section 4 examine the economics of two policy options meant to increase security of supply: investing in strategic petroleum reserves and conserving domestic gas fields, respectively. The final section concludes by answering the question whether such policy measures are efficient responses to risks in the supply of energy.

2. Security of energy supply: market response and market failures

2.1 Market responses to changing supply conditions: historical evidence

Over the past decades, energy markets experienced several disturbances, triggering a response by market participants. To illustrate, we mention a few events in the gas market that demonstrate how energy markets have dealt with changing supply conditions and, more generally, supply risks.

1 That said, the Directive also stresses the importance of removing barriers that prevent the use of interruptible contracts and adopting the use of real-time demand management technologies.

In New Mexico, one of three parallel interstate gas pipelines blew up in August 2000, causing the other two to temporarily shut down. For several weeks, this resulted in a 60-percent drop in the flow of gas (normally 2 billion cubic feet per day) from El Paso to the gas markets of Arizona and California. An EIA study (EIA 2000) into the effects of this disruption concluded that the markets were independently able to adjust and avoid severe gas shortages. This was accompanied by soaring gas prices – at least temporarily. According to the EIA (2000), the system stability was secured by several measures, such as alternate transportation, gas from storage and switching to other fuels to supplement the loss of natural gas supplies.

High prices and high volatility may be viewed as an unsatisfactory but inevitable consequence of liberalised energy markets.

In the United States, regulatory reforms to liberalise the gas market took place in the last three decades, with an initial deregulation of producer prices in response to supply shortages in the 1970s, which were caused by the regulatory price controls then in place (IEA 2004). Gas prices initially dropped during the 1980s and early 1990s as a result of the ensuing gas surplus. This trend was reversed in recent years, however, leading the IEA (2004) to characterise the market as being in a price crisis, meaning that there was no interruption of supply but that the available supply became more expensive. In response to increasing prices, demand fell significantly, both from electricity generators (which switched to alternative fuels) and from industry (which partly relocated production outside North America). On the supply side, capacity was expanded at existing LNG terminals, but many new terminals were planned too. The IEA concluded that – in terms of balancing supply and demand – security of supply was not expected to be a problem in the United States. The IEA expected that the prices would be able to balance supply and demand in North America, both in the short and the long term. However, high prices and high volatility may be viewed as an unsatisfactory consequence of this price mechanism.

The United Kingdom, too, has experienced a prolonged period of low gas prices during the 1990s after liberalisation and the introduction of competition in the first half of this century. Newbery (2000) describes how the abandonment of the centralised role of British Gas led producers to market their gas independently, bringing more gas to the market and leading to sustained low prices for many years because of the overcapacity that had been built up before liberalisation. Moreover, after connecting the British gas market to the continental European gas markets through the Zeebrugge-Bacton interconnector, UK prices typically remained below continental prices, resulting in exports to the continent for most of the time. Recently, this situation has changed, as in the United States. While UK prices remained below continental prices in the summer, some observers argued that the UK gas market was facing a potential shortage in the winters of 2005/06 and 2006/07. In 2005, forward prices for gas deliveries in January 2006 rose steeply to a peak of around 0.5 €/m^3, before tumbling back to some 0.35 €/m^3 (which was still more than twice average spot prices). Global Insight (2005) notes that within a period of a few years, supply and demand will be very tightly balanced. Both winters so far turned out to be relatively mild, except for some isolated cold spells. According to Global Insight, in spite of a drop in imports from the continent during some of these periods, the UK system managed well with the tightness on the market (Global Insight 2005). This was in part attributed to demand responding well to higher prices. Several authors have estimated the possible demand response at almost 10 percent of peak-day consumption. Moreover, in response to the higher gas prices, a large number of investment projects (LNG import terminals and new pipelines) were initiated – some of them have already been realised, others are expected to come on stream before 2008. Global Insight expects that the United Kingdom will see a significant surplus of import capacity by the end of the decade, notwithstanding the fact that the indigenous production continues to decline.

The lessons from these cases are that liberalised markets appear to ensure a balance between supply and demand and to provoke new investments in response to the expectation of higher prices. But it is also true that liberalised markets imply a more substantial demand response to temporary shortages than regulated markets. Short-term prices, in particular, will need to exhibit occasional spikes to trigger a market-clearing demand response. In the absence of market failures, market participants anticipate that disruptions can occur. In addition, prices internalise the impact of the reaction of each energy consumer to tight markets on other consumers. High prices during periods of shortages trigger investments aimed at efficiently managing such shortages. In a perfectly functioning market, if an incident occurs that reduces the supply of energy to a region, market participants immediately respond to the increase in price. Traders will deliver energy from elsewhere to the market while consumers will reduce their consumption, or both. Consumers who bought energy under long-term contracts might reduce their demand and sell the resulting surplus to other users. All in all, there are good reasons to assume that investments in production, storage, and transportation capacity together with a flexible response of energy consumers will take markets to a new equilibrium before too long.

High prices during periods of shortages trigger investments aimed at efficiently managing such shortages.

However, it cannot be denied that energy markets might be subject to market failures that hinder an optimal response to disturbances. Do both producers and consumers really respond efficiently to the challenges arising from changing energy markets? And to which extent do energy consumers take into account the cost of their consumption, in particular in relation to geopolitical risks?

2.2 Market failures

There are different types of market failures, but of particular relevance for the security of energy supply could be externalities, that is, costs or benefits that market agents ignore when making consumption or production decisions. If private costs are smaller than social costs, consumption or production will be higher than the social optimum. Bohi *et al.* (1996), for instance, view the relationship between oil consumption and imports, on the one hand, and the market power of oil-producing countries, on the other, as a clear example of a negative externality. Consumption of energy might cause an externality on security of supply as it raises the import dependence and, hence, the vulnerability of importing countries to geopolitical conflicts. As the Dutch Energy Council *Algemene Energieraad* (2005) argues, geopolitical risks will increase as future gas flows will be increasingly affected by political motives. One could imagine that foreign suppliers who are aware of the negative effects of a curtailment of gas supplies on European economies might use this knowledge to obtain political commitments by affected governments.

To some extent, incidental supply shortages due to political events are comparable to shortages due to technical supply difficulties. Efficient markets will expose market participants importing from unstable regions to higher prices because of the possibility of politically induced supply shortages. A key issue here – distinguishing it from the case of technical supply difficulties – is that the probability of an incident occurring may be endogenous. While the probability of a technical supply incident does not depend on the damage it causes, the attractiveness of politically motivated threats does change with its impact – and this impact rises with dependence on politically imperfectly reliable suppliers. Individual consumers neither take into account the impact of increased individual consumption on overall import dependency nor the price effect of an increasing import dependency. There is thus a negative consumption externality, resulting in too much consumption at too high prices compared to the welfare optimum. This might require a policy intervention, in contrast to a situation where (geo)political supply risks do not depend on the degree of import dependency (political instability in energy-exporting countries, for instance) and are reflected in the price of energy.

Besides negative externalities, positive externalities in energy markets exist too. For instance, market participants will insufficiently invest in the supply, or storage, of energy if they cannot capture the full benefits of the investments. This may happen if prices do not reflect the full scarcity value of energy, which could be a consequence of incomplete markets (such as absence of adequate short-term balancing prices), for instance. But it can also happen if investors fear that the government will interfere by imposing price caps (or creaming off the scarcity rents) when prices soar to extreme levels (see, for example, Bushnell 2005). Conversely, the implicit 'insurance' against high prices of such an intervention leads to a bias in investment towards higher risk alternatives.[2]

In well-developed energy markets, market participants internalise the risk of disturbances in supply and demand.

To conclude Section 2, in well-developed energy markets, market participants internalise the risk of disturbances in supply and demand. In practice, however, imperfect designs of markets and uncertainty about government policies in case of disturbances might result in sub-optimal decisions, such as insufficient investments in flexibility and excessive energy consumption. Too high consumption and prices might also be the result of markets not fully internalising the impact of energy consumption on dependency on a limited number of exporting countries. Market failures and imperfections of this nature might justify government intervention if the benefits of such intervention more than offset its cost. Bearing this condition in mind, we will next examine two policy options aimed at mitigating negative economic consequences of supply disturbances.

3. The economics of investing in Strategic Petroleum Reserves

3.1 Introduction

In this section we analyse the economics of investing in Strategic Petroleum Reserves (SPR). SPR are meant to intervene in the oil market when the oil price has risen sharply due to temporary[3] supply shocks.

Private investors in oil storage ignore in their decisions the benefit of the ensuing lower price for all other oil consumers; this requires government policy.[4] Moreover, the same holds at the level of entire countries: all countries participating in an SPR system contribute to the same decrease of the world oil price and the costs can be spread over the countries. This requires international cooperation.

There are in fact two official SPR systems: the system of the EU and the system of the OECD's International Energy Agency (IEA)[5]. Preceded by an OECD recommendation, the EU issued in 1968 a directive prescribing that member states should maintain strategic reserves of at least 65 days of net consumption. Again, preceded by an OECD recommendation, this level was raised to 90 days in 1972. Following the first oil crisis in 1973, the OECD established in 1974 the IEA. As from 1980, IEA participating countries are obliged to maintain an SPR of 90 days of net consumption. The two systems do not compete with each other but are complementary. Legal and procedural incompatibilities have been smoothed out. In what follows, we refer to both systems together simply as the SPR of the IEA[6].

2 Uncertainty over peak prices is sometimes mentioned as an impediment to efficient investments. Producers would not invest if they perceived the revenues to be too risky. This argument disregards the fact that not investing would be equally risky to those being short in energy: consumers or those from whom they contract energy.

3 Because of the limited size of the SPR, this instrument is of little use against a permanent price rise.

4 Note that for this to be the case, we need to assume that the negative effect of an oil price increase during the build-up of stocks is lower than the positive consumer welfare effect when stocks are released. A rationale for this might be that under normal circumstances, when stocks are built up, oil supplies would be more elastic than in the supply shock situation.

5 This paragraph draws heavily on Willenborg *et al.* (2004).

6 The IEA SPR are held by the United States, the countries of the EU-15, and by Australia, Canada, the Czech Republic, Hungary, Japan, Korea, New Zealand, Switzerland and Turkey. Poland and Slovakia are candidate IEA members. Norway is an IEA member without the SPR obligation.

The past decades have witnessed several temporary disruptions in the supply of oil, creating temporary oil price rises (see Table 1 and Figure 1). In very few cases, oil from the SPR was actually released. The last release from the IEA SPR was related to a natural cause: the Katrina hurricane in 2005.

At present, the SPR of the IEA comprises 1.4 billion barrels of oil, reflecting the required 90 days of net imports. Most of it is in government-controlled stocks. In the EU and in the United States, a unilateral increase of their own SPR has been discussed (see European Commission 2002 and Leiby and Bowman 2000, for instance). In what follows, we analyse the optimal size of the SPR from an economic point of view. We start with a sketch of the model for determining the optimal size of the SPR (Section 3.2), move on to a presentation of key parameter values used for the model (Section 3.3) and results of the model (Section 3.4), and then offer some concluding remarks (Section 3.5).

3.2 A model for optimising the size of the SPR

By computing marginal costs and marginal benefits, one can determine whether the size of the SPR is too small or too large. The optimal level of the SPR is found when marginal benefits equal marginal costs. The marginal costs per barrel of oil are simply the costs per year of buying and storing one barrel. For the sake of simplicity, we assume that these costs are independent of the size of the SPR. The marginal benefit per barrel – that is, the increase in annual benefits when the SPR is increased by one barrel – is the product of two parameters: (i) the benefit of releasing an extra barrel from the stock, thereby moderating a rise in oil prices and its negative effect on the economy; (ii) the number of supply disturbances per year that are large enough to exhaust the SPR and, hence, make this extra barrel necessary.

By computing marginal costs and benefits of the strategic petroleum reserve, one can determine whether its size is too small or too large.

This model can also be applied to other economic activities. For instance, using essentially the same model, the optimal investment in reserve capacity in the electricity supply industry has been studied in the 1970s and 1980s by several authors (see Chao 1983 for example). More generally, in early analyses of optimal investment in power generating capacity (Boiteux 1949), peak electricity demand compares to the large-enough supply disturbance in our SPR model.

Note that this model assumes risk neutrality. For any given size of the SPR, the net benefit of increasing the SPR is a stochastic variable because of the uncertainty of the frequency and timing of extreme supply disturbances. We consider only the expected value (average value) of the stochastic net benefit and ignore both the variance around this average and the risk of an extremely unfortunate outcome.

3.3 Parameter values

The marginal net benefit of the SPR depends on a number of parameters, specifically the probability and the size of oil supply disruptions (relative to the size of the SPR), the effect of these disruptions on the oil price, the negative effect of an oil price rise on the economy, and the costs of buying and storing oil. We will look at each of these parameters in turn.

3.3.1 Probability and size of oil supply disturbances

To assess the probability of future disturbances, it is useful to examine the frequency with which such disturbances have occurred in the past. During the second half of the last century, the world oil market experienced several supply disruptions, as shown in Table 1, which also reports their duration and the size of the loss. The length of these disturbances – which were primarily caused by political events in the Middle East – varied between two months (the Six-Day War between Israel and Arab countries in 1967) and around one year (OPEC Riyadh Pact). The magnitude of the disruptions varied between 0.6 million barrels a day (Nationalisation of oil firms in Algeria in 1971) and 4.6 million barrels/day (Gulf war in 1990). The largest disturbance (OPEC Riyadh Pact) followed from a planned cut in oil output that aimed at raising prices from their trough in the late 1990s rather than a supply disruption. Note that a release of oil from the SPR occurred only in very few cases.

Table 1. Oil market disturbances, 1950-2005

		Period	Duration (months)	Average gross loss (mbd)	Total gross loss (million barrels)	Release of oil from SPR (million barrels)
(1)	Nationalisation in Iran	1951-54	44	0.7	940	
(2)	Suez crisis	1956-57	4	2	245	
(3)	Syrian transit dispute	1966-67	3	1	65	
(4)	Six Day War	1967	2	2	120	
(5)	Libyan price dispute	1970-71	9	1	360	
(6)	Nationalisation in Algeria	1971	5	1	90	
(7)	Oil embargo USA and NL	1973-74	6	6	756	
(8)	Iranian revolution	1978-79	6	6	1,008	
(9)	Iran-Iraq war	1980	3	3	360	
(10)	Gulf war	1990	3	3	378	17
(11)	OPEC Riyadh Pact	1999-2000	12	12	>1,000	
(12)	Venezuelan strikes	2002-03	3	2	200	
(14)	Nigerian unrest	2003	6	0.3	50	
(14)	Iraq war	2003-04	19	1	600	
(15)	Katrina hurricane	2005			?	63
	Size of the present total SPR				1,400	

Sources: De Joode *et al.* (2004); IEA (2006b); EIA (2006a); US Department of Energy, DEO (2006).
Notes: mbd = million barrels per day; the total gross loss in the case of the Venezuelan strikes, Nigerian unrest, and the Iraq war is computed from the reported duration and average gross loss; the numbers in the last column (release of oil) are only rough indications.

One way to look at the data is to compare the size of the total gross loss during a market disturbance to the size of the SPR. Another way is to compare the maximum daily release of oil from the SPR to the size of the average gross loss in million barrels/day, regardless of the duration of the supply disruption. Leiby and Bowman (2000) cite such an analysis of the US Department of Energy. According to this analysis, the probability of exhausting a maximum daily release of 12 million barrels/day is once every century. Table 1 suggest that this has happened once in 1999-2000. This approach fits our model if we assume that adding an extra barrel to the SPR increases the maximum drawdown over the relevant time period also by one barrel; in other words, we assume that the maximum drawdown per unit of time is not a restricting limit.

Any value for the frequency and probability of exhausting the strategic petroleum reserve is highly speculative.

In conclusion, it is worth noting that any value for the frequency and probability of exhausting the SPR is highly speculative. However, to determine the optimal size of the SPR, one needs to make assumptions. As our base case, we use a once-in-a-century frequency; that is, we assume that once in a century, an oil market disturbance is severe enough to exhaust the SPR. As this is a rather arbitrary value, we will also conduct a sensitivity analysis.

3.3.2 Impact of disturbances on the price of oil

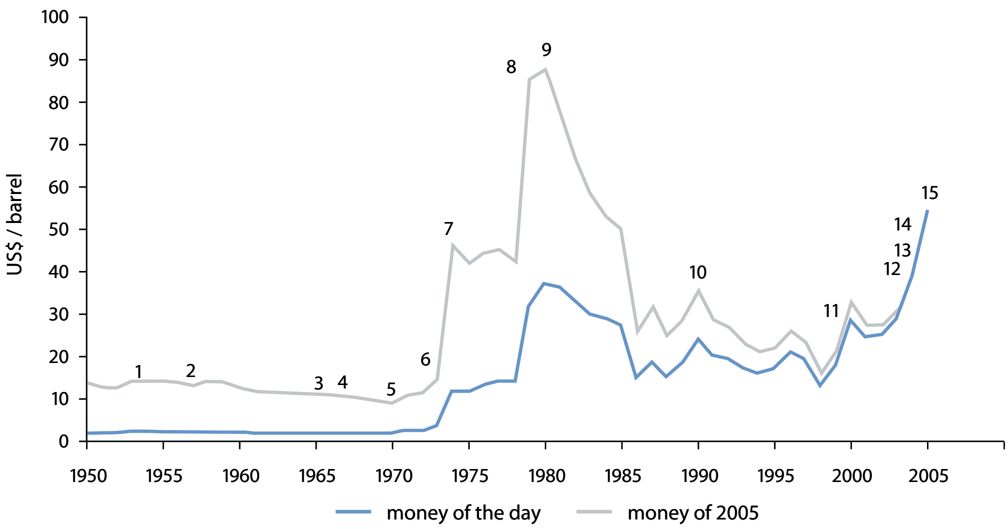
In the 1970s, the characteristics of the oil market changed deeply, with the birth of a powerful oil cartel as its key component.

Figure 1 shows that the price impact of various oil market disturbances varied significantly. In the 1950s and 1960s, the impact was negligible due to the organisational structure of the oil market. Between 1973 and the mid-1980s, the influence of disturbances on the oil price increased considerably. In the first oil crisis, in 1973-74, the price of oil surged by approximately 400 percent. Since then, the price of oil has never returned to its pre-1973 level. On the contrary, the price stayed at the new level for the remainder of the decade although the reason (the OPEC embargo on the United States and the Netherlands) that caused the price disappeared. The characteristics of the oil market had altered deeply, with the birth of a powerful oil cartel as the key component.

The second oil crisis, in 1978-79, lead to a further considerable price hike. Although the oil price stayed at that high level for several years, it turned out to be unsustainable because it stimulated production by non-OPEC producers, on the one hand, and energy savings by oil consumers on the other. Consequently, the cooperation among OPEC members was challenged, ultimately leading to a collapse of both the efficacy of the cartel and the price of oil. In 1985, the oil price fell to a level that became the average for almost 15 years.

Since the second oil crisis, the price effect of disturbances has been less clear. An enormous and gradual rise in the real price of oil has coincided with the supply disturbances 12 through 15 – as shown in Figure 1. However, there might be little causal relation between these two observations.

Figure 1. Crude oil price ($/barrel) and the oil market disturbances of Table 1



Source: Oil prices taken from BP, Statistical Review of World Energy, 2006.

As a sudden price spike hardly induces additional supply in the short term, the price effect of a supply disturbance is determined by the price elasticity of the demand for oil. One may then ask by how much prices have to rise (and demand to fall) so that the market clears when the supply of oil unexpectedly drops. The literature offers a number of estimates for this elasticity.

The Energy Information Administration (EIA 2004) of the US Department of Energy uses the following rule of thumb for an oil price of around 40$/barrel: "for every one million barrels per day of oil supply disrupted and not made good by other supplies (i.e. the net disruption size), world oil prices could increase by $4-$6 per barrel. […] At higher prices, $50 per barrel for instance, the rule of thumb would tend more towards the $5-$7 per barrel range". This amounts to a price rise of roughly 12 percent.

Considine (2001) also provides estimates of the price effects of supply disruptions. In a backwardation situation (when spot prices exceed futures prices), a shortfall of one million barrels/day is estimated to lead to a price increase of $4-$6 per barrel. In a contango situation (when spot prices are lower than futures prices), the estimated price rise is $7-$13. Using a more elaborate model with an imperfectly competitive market structure, Considine (2002) finds much smaller price effects than in the above simple competitive model: a disruption of one million barrels/day rises the oil price by 1$/barrel – an estimate that has been used by De Joode *et al.* (2004). To illustrate, for an oil price of 30$/barrel, the expected oil price increase amounts to 3 percent, and it would be even smaller at the currently high oil price.

Kingma and Suyker (2004) suggest that an unexpected decrease in the world oil supply of 1 percent triggers a short-term price increase of around 15 percent. For the current supply of about 84 million barrels/day, this implies a price increase of 18 percent for a supply disruption of one million barrels/day.[7]

Leiby and Bowman (2000), assume the short-term price elasticity of oil demand to range from -0.125 to -0.19, with an average of -0.16. For a supply of 84 million barrels/day, this average means that an unexpected drop in global supply of one million barrels/day would trigger a price increase of about 8 percent.

To summarise the studies reviewed above, the price increase estimated to result from an unexpected decline in global oil supply of one million barrels/day ranges from 3 percent to 18 percent.[8] Somewhat arbitrarily, we choose a value of 10 percent as a baseline assumption for our model, but we will also analyse the sensitivity of the results to this assumption.

3.3.3 Macroeconomic effects of oil price shocks

There has been much debate about the welfare loss incurred by (net) oil-importing countries as a result of higher oil prices. Usually, the welfare loss is defined by the effect of higher oil prices on GDP, with the link between rising oil prices and economic activity also being subject to considerable debate (Box 1 sketches competing views on this issue). The quantitative strength of this relation is summarised in the so-called oil price elasticity of GDP: the percentage change in GDP due to a one-percent change in the oil price.

The oil price elasticity of GDP is a parameter surrounded by considerable uncertainties ...

In general, the negative impact of an oil price increase on the GDP of oil-importing countries is not constant over time. In particular, an oil price hike might or might not trigger a recession (or prevent an economy from getting out of a recession), depending on the current position of the economy in the business cycle, economic and fiscal policies, and other factors. Hence, the oil price elasticity of GDP is a parameter surrounded by considerable uncertainties.[9]

Mory (1993), for instance, estimated an elasticity of -0.055, which is close to value of -0.054 estimated by Mork *et al.* (1994). Leiby and Bowman (2000) used this value in their study on the SPR of the USA. Labonte (2006) is the last of a series of updates on the effects of oil shocks on the economy – prepared for the US Congress; he refers to a study of Jimenez-Rodriguez and Sanchez (2004) that suggests an elasticity of -0.04 to -0.06. The IEA (2004) reports a reduction of 0.4 percent of GDP due to an oil price increase of 10$/barrel (from $25 to $35), implying an elasticity of -0.010 to -0.014 – a value much lower than the figures above.

7 For a total oil supply of 84 mbd, a drop of 1 mbd is equivalent to a drop of about 1.2 percent, thus requiring a price increase of 1.2 times 15 percent to clear the market.

8 Note that these short-term elasticities are significantly above estimated long-term elasticities, that is, those associated with permanent price rises. See for instance IEA (2006a, p. 287).

9 Many studies analyse the effect of a permanent rise of the oil price and not the effect of a temporary rise associated with oil supply disturbances. Note also that for non-US countries, the effect of a change in the oil price in dollars depends on changes in their exchange rates *vis à vis* the US-dollar.

Box 1. The link between the price of oil and economic activity – competing explanations[11]

Several explanations have been put forward for the inverse relationship between oil price and aggregate economic activity. Brown *et al.* (2002) categorise the explanations into four groups.

The classic 'supply side shock' explanation mentions the rising price of a key input factor as the trigger. Increasing costs of production reduce output growth and, hence, productivity growth. Consequently, the growth of real wages declines and consumers save less or borrow more with view to smoothing consumption. As a result, the real rate of interest rises, reducing the demand for money and, thus, increasing inflationary pressure unless – that is – the supply of money is reduced too. If nominal wages are sticky downward, unemployment will grow, further reducing aggregate production.

A totally different perspective follows from the 'income transfer' explanation. This approach stresses that rising oil prices transfer income from oil-importing countries to oil-exporting countries. As the latter have a lower propensity to consume, global spending and, hence, production declines, particularly in the oil-importing countries. This effect is partly offset by the accompanying growth in aggregate savings that reduces the real rate of interest and thus stimulates investment and production.

Another approach – the 'real balance effect' explanation – focuses on the role of money supply. This explanation states that a rising oil price leads to an increase in the demand for money that is not (fully) matched by an increase in money supply. Consequently, interest rates rise and economic growth slows down.

The final approach sees 'the failure of monetary policy' as the major explanation. According to the adherents of this approach (Bernanke *et al.* 1997, for instance), inadequate monetary policies were the major cause for the relationship between the oil price and economic growth. In the past, central banks often tightened the supply of money with a view to restraining oil-priced induced inflationary pressures, thereby exerting a contractionary impact on the economy. This view has been questioned by others (see Hamilton and Herrera 2001 and Hooker 1999, for instance).

According to Brown *et al.* (2002), the 'classic supply side shock' explanation offers the best account for the inverse relationship between oil price and aggregate economic activity.

Using CPB's Athena simulation model of the Netherlands, De Joode *et al.* (2004) computed the effect of an oil price rise on the Dutch economy.[10] The sensitivity of the Dutch economy with respect to the oil price is also discussed in CPB (2004), suggesting that a rise in the oil price of 10$/barrel (from $35 to $45) lowers GDP by 0.4 percent, implying an elasticity of -0.014 to -0.018.

… with elasticity estimates covering a range from -0.01 to almost -0.06.

All in all, estimates of the oil price elasticity of GDP cover a wide range (from -0.01 to almost -0.06). For our analysis of the cost and benefits of increasing the SPR, we will use a value of -0.03. For the Netherlands, we choose a value of -0.02, as this country also benefits from higher oil prices through is exports of natural gas, the price of which is positively correlated to the oil price.

10 CPB is the Netherlands Bureau for Economic Policy Analysis.
11 This Box draws heavily on De Joode *et al.* (2004, p.52).

3.3.4 The costs of buying and storing oil

Oil storage costs depend on geological characteristics of the storage facility and its drawdown capabilities.

The costs of the SPR consist of the costs of buying and storing the oil. In the simplest case, the annual costs of buying the oil is equal to the interest forgone (value of the oil multiplied by the discount rate). Profits may be made when selling high (during a crisis) and buying low (after the crisis), which reduces the costs. Storage costs depend on geological characteristics of the storage facility and its drawdown capabilities.

In the Netherlands, public oil stocks are mainly stored in salt caverns. Based on government information, De Joode *et al.* (2004) estimate the annual costs of buying and storing oil at €2.4/barrel.

Analysing the SPR costs for the United States, Leiby and Bowman (2000, table 4, p. 26) use a net-present-value cost of about 5$/barrel (in 1996 prices). It is unlikely that this very low figure includes the buying of the oil. For the United States and the EU, we simply use the estimated €2.4/barrel per year for the Netherlands.

As noted above in Section 3.1, it pays to spread the costs of the SPR over many participants. For instance, the share of the Netherlands in the SPR of the European Union is 2.9 percent (see De Joode *et al*. 2004), implying an annual cost to the Netherlands of around €0.07 per barrel of the EU SPR.

3.4 Results: efficiency of strategic petroleum reserves

Table 2 shows the parameter values discussed in the previous sub-section, the results of the cost-benefit analysis under these assumptions, and the 'break-even' parameter values that would make marginal economic costs equal the marginal economic benefits of the SPR.

Row [A] indicates the countries that coordinate their SPR activities and row [B] shows the country – or group of countries – for which the cost-benefit analysis is carried out. To illustrate, the second column pictures the cost-benefit analysis for the Netherlands when this country jointly holds strategic petroleum reserves with its EU partners; the first column shows again marginal costs and benefits for the Netherlands, but this time under the assumption that the Netherlands invests in its own SPR. The crucial difference between these two cases is that when the Netherlands – or any other country – jointly holds reserves with partner countries, it carries only a fraction of the costs of increasing strategic reserves (as indicated in row [4]) while fully capturing the benefits – together with its partners – given that the beneficial oil price effect of releasing oil from the SPR has public-good characteristics.

As the first column shows that, for a small country like the Netherlands, the expected marginal benefit of the SPR (€0.02/barrel per year) is negligible compared to the marginal costs of its own SPR (€2.4/barrel per year). Hence, this country on its own should decrease its SPR. Assuming that this does not measurably raise the probability of fully exhausting other SPR (row [5]), the optimal Dutch SPR is zero.

The Netherlands clearly benefits from being part of a much larger SPR (second column), as shown by the much lower marginal costs to the Netherlands of contributing to the SPR of the EU-15 (€0.07/barrel per year). However, the bottom line remains the same: the SPR is too large, as the marginal benefit is still negative (-0.04 €/barrel per year) and the marginal cost-benefit ratio remains larger than one.

Table 2. Cost and benefits of increasing the SPR

Country coverage					
[A]	Countries coordinating their SPR activities	NL	EU-15	EU-15	US
[B]	Perspective of cost-benefit analysis	NL	NL	EU-15	US
Estimated/assumed parameter values					
[1]	Oil price increase resulting from a decline in oil supply by one million barrels/day	10%	10%	10%	10%
[2]	Oil-price elasticity of GDP	–0.02	–0.02	–0.03	–0.03
[3]	Annual GDP of country (region) in row [B]	€450bn	€450bn	€10,000bn	€8,000bn
[4]	Fraction of country/region [B] in the SPR of [A]	1	0.029	1	1
[5]	SPR fully exhausted once in …	100 years	100 years	100 years	100 years
	Marginal costs (per year) of the SPR				
[6a]	Costs to country/region in row [A]	2.4 €/bbl	2.4 €/bbl	2.4 €/bbl	2.4 €/bbl
[6b]	Costs to country/region in row [B] = [6a]x[4]	2.4 €/bbl	0.07 €/bbl	2.4 €/bbl	2.4 €/bbl
Results of cost-benefit analysis under baseline assumptions					
[7]	Expected marginal benefit per year of the SPR = (–[1]x[2]x[3] / [5]) / (365 million barrels per year)	0.02 €/bbl	0.02 €/bbl	0.82 €/bbl	0.66 €/bbl
[8]	Net marginal benefit per year = [7]–[6b]	–2.38 €/bbl	–0.04 €/bbl	–1.58 €/bbl	–1.74 €/bbl
[9]	Marginal cost/benefit ratio = [6b]/[7]	97	2.8	2.9	3.7
Break-even parameter values (resulting in net marginal benefits of zero in [8] and a cost-benefit ratio of 1 in [9])					
[1′]	Oil price increase resulting from a decline in oil supply by one million barrels/day		28%	29%	37%
[2′]	Oil-price elasticity of GDP		–0.06	–0.09	–0.11
[5′]	SPR fully exhausted once in …		35 years	34 years	27 years
[6a′]	Marginal costs (per year) of the SPR		0.85 €/bbl	0.82 €/bbl	0.66 €/bbl

Notes: Estimated/assumed parameter values as described in Section 3.3. Rows [2], [3], [4], [6a], and [6b] depict country- or region-specific parameters; rows [1] and [5] show global oil market parameters. Rows [5] and [5′] are the reciprocals of the probability of fully exhausting the SPR. The crucial calculation is in row [7]; to illustrate, for the second column, the calculation of the expected marginal benefit of increasing strategic reserves in row [7] is: { – (10 percent) x (–0.02) x (€ 450 billion per year) / (100 years) } / (365 million barrels per year) = 0.02 € per barrel per year. End results have been rounded.

From the perspective of the EU-15 (third column), the results of the cost-benefit analysis differ only slightly from the results in the second column, with the cost-benefit ratio increasing to 2.9. Note that the Dutch share in the GDP of the EU-15 of 4.5 percent is larger than its share of 2.9 percent in the EU SPR. If these two shares were equal and if the oil-price elasticities of GDP were equal, too, there would be no difference in the marginal cost-benefit ratio between the second and the third column.

For completeness we note that from the perspective of the United States, increasing its SPR would be economically unviable too (last column). Indeed, the cost-benefit ratio is even less favourable than in the case of the EU because the US economy is smaller than the EU economy. It should be noted, however, that our results for the United States do not agree with the conclusions of Leiby and Bowman (2000). But as we have pointed out in Section 3.3.4, their analysis seems to be based on an estimate of the marginal costs of holding strategic reserves that we consider as far too low.

So far, the overall conclusion resulting from our analysis is that extending the SPR at the EU level or US level is not efficient, as the marginal costs exceed marginal benefits. Even extending the analysis to the entire IEA SPR might not be enough to reach the marginal break-even point. To illustrate, adding the GDP of the major oil-importing IEA members – Australia, Canada, Japan and South Korea – to the GDP of the EU-15 and the United States gives an annual GDP of roughly €25,000 billion. Using this figure in the third (or last) column of Table 2 would raise the expected marginal benefit to €2.1/barrel per year – still slightly less than the marginal cost of €2.4/barrel.

But how robust are these conclusions to changes in the underlying assumptions?[12] To shed light on this question, we proceed in two steps: we first calculate for each of the parameters its break-even value, that is, the value that would result in marginal net benefits of zero (the results of these calculations are shown in the bottom part of Table 2);[13] we then compare these break-even values with the range of values found in the literature and discussed in Section 3.3.

As the probability of fully exhausting the strategic petroleum reserve is particularly uncertain, the balance of marginal costs and benefits might well change considerably under alternative assumptions.

As for rows [1′] and [6a′], the three last columns show parameter values that are outside the range discussed in Section 3.3. Specifically, the impact of a change in the world oil supply on oil prices would have to be significantly larger than what historical evidence suggests while the costs of buying and storing oil would need to be far lower than they currently are. Therefore, our conclusions are fairly immune to the uncertainty surrounding these parameters.

However, the break-even values in row [2′] and row [5′] are reasonably close to some of the estimates reviewed above. As the probability of fully exhausting the SPR (row [5′]) is particularly uncertain, the balance of marginal costs and benefits might well change considerably under alternative assumptions. A reasonable conclusion here is that the SPR of the EU-15 might in fact not be too large. This is true, in particular, when we extend the analysis again by including other IEA countries, thus increasing the GDP affected by oil price movements. In fact, in this case the break-even frequency of fully exhausting the SPR is once in about 86 years – not too far off our baseline assumption. Moreover, if one perceives the risk of a supply disturbance to be large, extending the SPR might be viewed as efficient, in particular by risk-averse decision makers.

3.5 Additional observations and conclusions

A few more observations about the economic analysis of the SPR are worth mentioning. The analysis considers expected net marginal benefits as the key criterion for assessing the SPR. Actual benefits

12 A general observation might be useful in this context. The effects of alternative assumptions are relatively easy to gauge from Table 2. For instance, a change in the marginal cost of the SPR (row [6b]) feeds directly through to the net benefit row [8] and the cost-benefit ratio [9]. Doubling (halving) the parameters in rows [1] and [2], doubles (halves) the expected marginal benefit shown in row [7]. For the number of years in row [5], the reverse holds. For instance, halving this number from 100 to 50 (thus doubling the probability of fully exhausting the SPR), doubles the expected marginal benefit in all columns, with the net marginal benefit per year (row [8]) amounting to -2.35 €/bbl, -0.02 €/bbl, -0.76 €/bbl, and -1.08 €/bbl. Hence, net marginal benefits remain negative and the conclusions do not change. But with another doubling of expected marginal benefits the conclusions will change, except in NL/NL-case.

13 Break-even values are not computed for the NL/NL column since zero marginal net benefits are entirely out of reach in this case. To illustrate, zero marginal net benefits would require a full exhaustion of the SPR not once in a hundred years (baseline assumption) but almost every year.

might be quite different, however. Moreover, the actual process of an oil supply disturbance and the release of oil from SPR are more complicated than assumed in this model. For example, De Joode *et al.* (2004) pay much attention to the fact that oil can be released only in limited quantities (the drawdown pattern).

Perhaps a more serious concern is that the SPR might replace regular supply. More specifically, the SPR might crowd out private investment in storage capacity and contracts for reducing demand of industrial consumers, both relying on periods of high prices to make such activity profitable. If oil from the SPR is released into the market when there is upward pressure on oil prices (with a view to keeping prices in check), the attractiveness of such investments and contracts will suffer, ultimately reducing the storage supplied by the market. Ironically, as a result of this crowding out, calls for government intervention might grow.

The strategic petroleum reserve might crowd out private investment in storage capacity and contracts for reducing demand of industrial consumers.

As a final comment, there is a possibly strategic role for the SPR: the threat of releasing oil might deter OPEC from trying to raise the price. As EIA (2006) states, most of IEA actions have not resulted in the release of oil, but the mere existence of the SPR might nevertheless have been valuable.

To conclude, it is perhaps not surprising that the cost-benefit analysis presented in this section cannot yield a clear-cut answer to the question of whether or not it makes economic sense to extend the SPR. Ultimately, this question needs a political answer, but the analysis offered here provides a rational economic framework for finding it.

4. The economics of conserving domestic gas reserves

4.1 Dutch gas-depletion policy: capping output of the Groningen field

Since the first oil crisis in the 1970s, the Dutch government has pursued a gas-depletion policy that rests on two related pillars: conserving gas from the Groningen field – a giant, low-cost, and flexible to operate onshore gas field of around 1,100 billion cubic metres (bcm) – and encouraging production from smaller gas fields. In the Dutch Gas Act (Article 55 of the so-called *Gaswet*), the Minister of Economic Affairs has introduced a cap on production from the Groningen field, which replaces the national production cap that had existed before. In a letter to the Parliament, the Ministry of Economic Affairs (2005) has set a cap on Groningen of, on aggregate, 425 bcm for the period of 2006 to 2015. As this cap only limits aggregate production, it allows for the swing function of the Groningen field, that is, larger production when demand is high during the winter season and lower production during the summer.

The purpose of this section is to analyse the welfare effect of this cap. To this end, Section 4.2 examines the impact of the cap on the European gas market. Section 4.3 considers the costs, benefits, and the welfare effect (benefits minus costs) of the cap.

4.2 Effects of the cap on the European gas market

To analyse the welfare effects of the cap on Groningen, we first have to assess its impact on the production from this field and the natural gas market more generally. We use the NATGAS model (described in Zwart and Mulder 2006) to examine the effects of the cap on the European natural gas market under four scenarios, which we have labelled Baseline, Competition, Sellers' Market, and High Price, respectively (Box 2 offers a brief description of these scenarios). The key question is: what is the effect on prices, investment in and use of infrastructure, and on international gas flows of this policy measure?

Box 2. Alternative gas market scenarios

We analyse the welfare effects of the cap on Groningen under four gas market scenarios, which we have called Baseline, Competition, Sellers' Market, and High Price, respectively. There are three criteria that specify each scenario: the degree of competition in the European gas market, demand growth, and LNG prices – which depend on global competition.

Definition of scenarios	Baseline	Competition	Sellers' Market	High Price
Degree of competition in gas market	modest	high	low	very low
Annual growth of gas demand	1.5%	1.0%	1.5%	2.0%
Average threshold price for LNG	0.15 €/m^3	0.13 €/m^3	0.18 €/m^3	0.28 €/m^3

In the baseline scenario, competition in the European gas market is modest because, for instance, of insufficient cross-border transmission capacity and a limited number of suppliers in national markets. Competition in global energy markets is such that LNG would become available for Europe at a price above €0.15 per m^3 (in real terms), which compares to an oil price of about $34/barrel.

In the competition scenario, conditions for competition are more favourable, resulting in fairly fierce competition in European natural gas markets. Moreover, global competition is assumed to be strong too, depressing the threshold price at which LNG becomes available for Europe to €0.13 per m^3 (about $30/barrel of oil).

In the sellers' market scenario, suppliers' market power is stronger than in the baseline scenario, both in the European natural gas market and in global energy markets. The threshold price for LNG to become competitive is significantly above the threshold in the baseline scenario (0.18 €/m^3 and $40/barrel of oil – both in real terms).

In the high price scenario, the degree of competition in European gas markets is assumed to be very low. Economic growth is strong and there is a certain dash-for-gas, in particular by electricity producers, generating buoyant demand for gas. High oil prices, strategic behaviour of non-EU suppliers, and a high price needed to attract LNG to Europe cause gas prices to roughly remain as in 2006.

In estimating the effect of imposing a cap on Groningen production, one has to take into account that Groningen produces low-calorific (low-cal) gas, which is only consumed in a relatively small market.[14] Apart from consuming it directly (mainly by end users in the Netherlands, Germany, Belgium, and northern France), low-cal gas can also be marketed by mixing it with high calorific (high-cal) gas that has a larger-than-average energy content. Norwegian gas is an example of such gas, and given the expected increase in Norwegian imports, there is some scope for growth of the low-cal gas market as a result.

14 See Zwart and Mulder (2006) for a description of the characteristics of the natural gas market.

Lower output from the Groningen field as a result of the cap will have to be compensated for by either an increase from other sources, or a decrease in demand. In the low-cal gas market, the most important other sources are German production and high-cal gas that is quality converted into low-cal gas. For the latter, there is currently a limited capacity in the Netherlands and its utilisation rate is high.[15] Additional conversion capacity is available in Germany. An increased supply of quality-converted gas would mitigate the increase in low-cal gas prices resulting from a decline in the production of Groningen. As a consequence of the larger demand for high-cal gas, prices rise and production (from the Dutch small fields) and imports of high-cal gas are likely to expand – at least in the long run. In the short term, however, the response of high-cal supplies would be limited because of long lead times for new infrastructure investments. This being said, a short-term supply response could come from increased LNG imports in the nearby markets – Belgium and the United Kingdom, for example – which could experience a diversion of LNG ships from non-European markets – the United States, for example – because of higher prices in continental Europe.

Turning to the demand side of the market, in the short run, higher prices are likely to reduce consumption only slightly (perhaps mainly by power stations using low-cal gas). In the long run, however, a drop in low-cal gas supply and higher prices might reduce investments in gas-fired power plants – favouring other technologies, such as coal-fired power plants.

With a cap on Groningen, one would expect a reduction in the output of Groningen because the operator is no longer free to choose the profit-maximising production path. In these circumstances, the shortfall in the cap triggers an increase in output by Dutch small-fields and other European producers, additional imports from outside Europe, or a decline in demand (because of higher prices).[16] However, as the profit-maximising output might not exceed the cap, the latter might be non-binding, implying no shortfall in Groningen output and, thus, no change in the production of other producers, imports, and demand.

With a cap on the production from the Groningen field, one would expect a reduction in its output because the operator is no longer free to choose the profit-maximising production path.

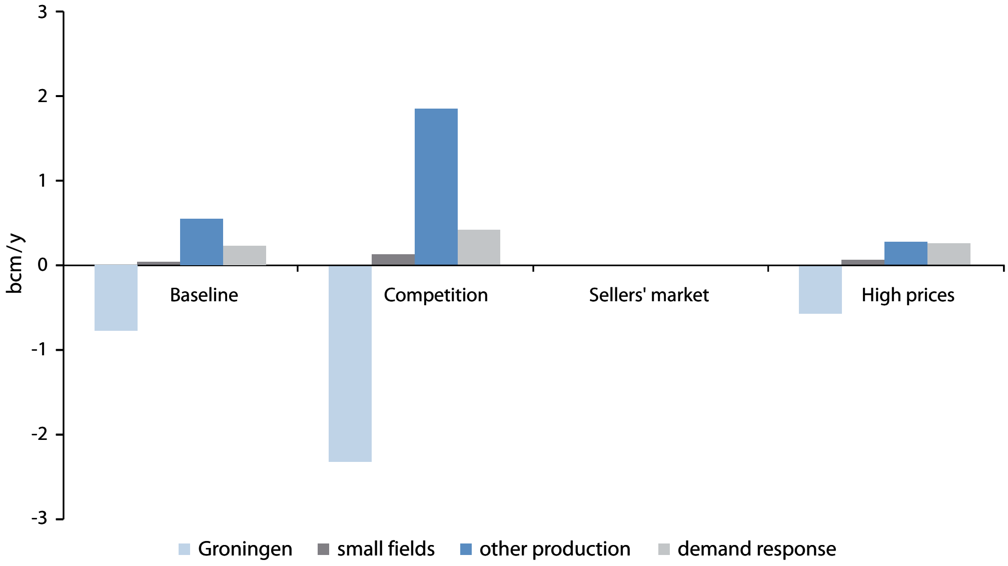
Figure 2 pictures the estimated response to the cap of the Groningen field itself, Dutch small-fields, other European and non-European producers, and of demand under the four scenarios. It turns out that the cap is non-binding in the sellers' market scenario (unconstrained profit-maximising output does not exceed the cap), while it is binding in all other scenarios. This being said, in the baseline scenario and the high price scenario, the cap has only a moderate effect on actual production, amounting to about 0.8 bcm per year and 0.6 bcm per year, respectively. The competition scenario shows the largest impact on Groningen production (an annual average drop of 2.5 bcm over 20 years) and, thus, on other production, imports, and demand. In this scenario, the assumed strong competition in the European gas market reduces the options for strategic behaviour, resulting in a relatively high profit-maximising output, which – however – cannot be attained due to the cap.

The relatively moderate impact on small-fields production shown in Figure 2 is because current capacities are already well utilised and the rise in prices estimated to follow from the cap is too small (0.0007€/m^3 on average over 20 years) to induce significant investment in additional capacity. All in all, the cap on Groningen is estimated to result in only a minor price change on the European natural gas market, mainly because of a fairly elastic response by consumers, other producers, imports and – though to a lesser extent – Dutch small-fields production.

15 See , for instance, DTe (2004) for a discussion of currently available Dutch quality conversion capacity. DTe is the Office of Energy Regulation, a chamber within the Netherlands Competition Authority.

16 It should be noted that these are the effects while the cap is place. When it will be removed in the future (and one enjoys the prolonged life of the field) the effects are reversed.

Figure 2. Effects of the cap on Groningen on the European natural gas market under alternative scenarios (in billion cubic metres per year)



Source: Mulder and Zwart (2006)

Notes : Effects over a 20-year horizon.

4.3 The welfare effect of the cap on Groningen

The welfare effect of the cap on Groningen depends on its impact on the production from this field and the ensuing changes in the European gas market.

Obviously, the costs and benefits – and thus the welfare effect – of the cap on Groningen depend on its impact on the production from this field and the ensuing changes in the European gas market – as discussed above.

As for costs, there are two main cost components to consider when the cap on Groningen binds. First, conserving the Groningen gas field and thus postponing production and sales reduces the present value of the producer's surplus accruing to the operator of the Groningen field. Second, all other things being equal, gas consumers face higher prices today and lower prices in the future, reducing the present value of the consumers' surplus. None of these costs materialise – they are zero – in the seller's market scenario when the Groningen cap does not bind.

As shown in more detail in Mulder and Zwart (2006), for a discount rate of 5 percent (in real terms), the estimated drop in the producer's surplus ranges from €30 million in the high price scenario to €540 million in the competition scenario. The present-value cost to consumers ranges from €140 million in the baseline scenario to €435 million in the competition scenario. Most of the costs to consumers fall on consumers of low-cal gas (that is, the quality of gas produced by the Groningen field), and only a small part on high-cal gas consumers. As shown in Table 3, in present-value terms, total economic costs are estimated to range from €280 million in the high price scenario to almost €1 billion in the competition scenario. For completeness, Table 3 also shows the impact of the cap on output from the Groningen field.

Turning to the expected benefits of the cap, three types of benefits are of particular importance: benefits accruing to small-fields producers, benefits due to a higher reliability of gas supply, and – most important for the topic discussed in this paper – benefits due to an enhanced security of gas supply. We take a brief look at all three categories, and more details can be found in Mulder and

Zwart (2006). Upfront, it is useful to note that the cap brings no benefits when it is non-binding, that is, in the sellers' market scenario.

Table 3. Welfare effect of the cap on Groningen under alternative gas market scenarios

	Baseline	Competition	Sellers' market	High price
	Present value in millions of euros (unless otherwise indicated)			
Costs	500	975	0	280
Benefits				
Additional small-fields producers' surplus	35	145	0	35
Reliability of supply	10	20	0	10
Security of supply	< 200	< 500	0	< 100
Welfare effect = benefits-costs	< –255	< –310	0	< –135
Memorandum item:				
Decline in Groningen output per year (in bcm)	0.8	2.5	0	0.6

Source: Mulder and Zwart (2006).
Notes: Annual cap of 42.5 billion cubic metres on average; discount rate of 5 percent.

Benefits to small-fields producers come in two forms. For one thing, a rise in gas prices due to the cap increases small-fields producers' surplus. Using a discount rate of 5 percent, the present value of this increase is estimated to range from €35 million (baseline and high price scenario) to €145 million (competition scenario) – as shown in Table 3. For another, a cap on Groningen could change its role as a balancing field, thereby allowing small fields to produce at roughly constant rates. However, for all four scenarios, this effect is estimated to be negligible, and it is not shown in Table 3.

Benefits due to a higher reliability of supply reflect the fact that the Groningen field can act as a buffer to make up for temporary supply or demand fluctuations. The cap on Groningen extends the lifespan of this field and thus the lifespan of the buffer. A corollary is that investment in alternative buffers (additional short-term storage, for instance) can be delayed. Hence, the benefit of this measure comes in the form of delaying investments in alternative buffers.

Benefits due to a higher reliability of supply reflect the fact that the Groningen field can act as a buffer to make up for temporary supply or demand fluctuations.

An appropriate alternative buffer would be an expansion of LNG storage capacity that is large enough to cover a one-day supply shortage of 20 million cubic metres. The annual cost of this alternative is estimated at €22 million. We assume that investing in this alternative becomes necessary once the depletion of the Groningen field has progressed to a point where it can no longer act as a buffer. When that point will be reached is hard to predict, but as De Joode *et al.* (2004), we assume this to occur when Groningen reserves have dropped to 400 bcm.

The benefit of capping Groningen is to push this moment further into the future, by several years – depending on the gas market scenario. For these years, one avoids the annual costs of expanding LNG storage capacity. The present value of avoided costs therefore depends on the number of years the investment is postponed and on when the storage needs to be built. Our estimates show that the present value of avoided costs is fairly small, ranging from €10 million in the high price scenario to €20 million in the competition scenario (see Table 3). Indeed, this may still overstate the benefits because the Groningen field cannot act as a buffer against short-term fluctuations during periods of very high demand (winter), whereas alternative storage can.

When discussing investment in strategic petroleum reserves in Section 3, we stressed the possibility of crowding out. The risk that policy measures might crowd out profitable private investment arises, too, in the context of measures to provide a buffer for short-term gas supply and demand fluctuations. However, if we assume that the back-up facility provided by the Groningen field is not used with a view to stabilising prices, but only in emergency situations to avoid forced disconnection of consumers, the effect on private investment is probably low.

This takes us to the third type of benefit: enhanced security of gas supply. As Dutch gas reserves dwindle over the next decades, the Netherlands will turn into a net importer. In this situation, the economy will be increasingly vulnerable to gas price rises. Higher prices, or even price crises, might be incidental, for instance as a result of unusually cold winters, technical supply disruptions, or geopolitical conflicts. There might also be structural reasons for higher gas prices – such as increased market power of a potential future gas cartel. In the remainder of this sub-section, we analyse capping Groningen as a means to provide 'strategic storage' to be used in times of incidental gas supply shortages. In contrast to the reliability benefits discussed above, of interest here are not one-day supply shortages but shortages over a longer period of time.

If market failures leave market participants incompletely exposed to the risk of supply problems, they will invest too little to respond to low-probability supply problems. Solving the market failure itself would be the optimal response here, but if this is deemed unfeasible, the government may step in and reduce the risk of supply shortages – including sharp price increases – by releasing gas from strategic storages.

Leaving the flexibility of the Groningen field looming above the market to interfere when prices rise, reduces the attractiveness of private investment in gas storage.

The flexibility of the Groningen field essentially fulfils this storage function, and conserving Groningen would extend the lifespan during which it can be used to mitigate future price effects of occasional severe winters or technical supply problems. By keeping prices lower in these circumstances, Dutch consumer welfare is increased. However, as with policy measures to reinforce short-term reliability, one should recognise that by effectively capping prices, private-sector investment in alternative storage (LNG import terminals or depleted gas fields, for instance), which relies on occasional price hikes, might be crowded out. Put differently: leaving the Groningen flexibility looming above the market to interfere when prices rise, reduces the attractiveness of private investment in gas storage.

Having said this, we can try to answer what the benefit will be of using Groningen to prevent excessive price hikes under periodic scarcity conditions. Similar to our discussion of short-term reliability, an upper limit for this benefit can be found by considering the cost of other means to achieve this goal – cost that will be avoided due to the cap on Groningen. A natural candidate is strategic storage capacity from which gas can be released in a price crisis. Some countries, Italy in particular, have invested in such storage. As the cost of such storage is estimated to be high (see IEA 2004), the security-of-supply benefits of conserving Groningen might be high, too.

More specifically, we assume that depleted gas fields would be used as strategic storage capacity. As for the size of the capacity needed, we note that the average monthly Groningen production was around 3 bcm below peak production in 2004. If we consider a price crisis of three months (remember that strategic petroleum reserves are required to equal 90 days' consumption), Groningen would be able to supply 9 bcm, on average. Strategic storage in depleted gas fields would have to be in place when the flexibility of the Groningen field is insufficient to produce this additional output, which we again assume to be when the field's remaining reserves have dropped below 400 bcm.

Based on data from ILEX (2005) on storage costs, we estimate the total annual costs for providing storage in depleted fields at €0.05-€0.07 per cubic metre, with the range reflecting alternative discount rate assumptions. The effect of capping Groningen is to postpone the moment when such strategic capacity is necessary to replace the flexibility of Groningen. When this will be depends on the underlying gas market scenario.

As shown in Table 3, our estimates indicate that keeping strategic storage is costly, implying that using Groningen instead of storage entails large benefits, amounting to a maximum of €500 million in the competition scenario (this is for a discount rate of 5 percent). Yet, as other measures dealing with security of supply might be more efficient than investment in strategic storage (measures to influence the demand response, for instance), these calculations overestimate the security-of-supply benefits of Groningen, and they can only be considered an upper bound. This is also because they do not account for possibly crowding out private investment in strategic gas storage.

Considering the economic costs and benefits, the average annual cap on Groningen of 42.5 bcm is estimated to be welfare reducing unless the cap is non-binding. More specifically, the negative welfare effect ranges from (at least) €135 million in the high price scenario to (at least) €310 million in the competition scenario. As shown in Mulder and Zwart (2006), different discount-rate assumptions (3 percent and 7 percent instead of 5 percent) have significant effects on both costs and benefits, but do not change the conclusion that the overall welfare effect is negative if the cap is binding. What is more, this conclusion holds for other reasonable assumptions about the price of LNG, the availability of Dutch offshore gas infrastructure, and the level of tax distortions.

5. Conclusion

The main conclusion from the two policy measures considered in this paper is that security-of-supply measures are unlikely to be welfare enhancing, but they might be in specific circumstances. Considering the economic costs and benefits of such measures, it would often be wiser to accept the consequences of supply disturbances than to avoid them. But it is also true that estimating the benefits of security-of-supply measures is a task surrounded by considerable uncertainties. Governments should thus proceed carefully in taking such measures. If serious market failure is detected, attention should be paid to properly design corrective measure.

Estimating the benefits of security-of-supply measures is a challenge and a task surrounded by considerable uncertainties.

But if markets function reasonably well, prices will give market participants incentives to prepare for and respond to supply disturbances, enabling an efficient balancing of supply and demand not only under normal market conditions but also during periods of stress. It is true that even well-functioning markets might be prone to price spikes, as evidence from both the gas and electricity markets demonstrates. However, the welfare cost of price spikes is often small compared to the cost of policies aimed at preventing them. Given the market's potential to efficiently cope with energy supply disturbances, government action to improve the functioning of energy markets (such as pricing externalities and facilitating transactions between market participant) might be more efficient than measures requiring large up-front investments or measures restricting options of profit-maximising agents.

However, cost-benefit analyses can offer only part of the information needed for decision making. Not all costs and benefits are measurable and those that are not need to be accounted for as *pro memoria* items. Examples include the possible crowding out of private activity geared towards enhancing security of supply by government action. Moreover, the distribution of costs and benefits within society generally plays an important role in the decision-making process. In our analysis, we analysed the distribution effects at a fairly aggregate level only. Another issue concerns the degree of risk aversion underlying cost-benefit analyses. Decision makers might act in a rather risk-averse manner – for instance because they fear for their reputation in times of supply disturbances. But it is also possible that societies as a whole are more risk averse than often presumed. In both cases, the results of cost-benefit analyses are likely to shift in favour of security-of supply policies.

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