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Common Energy Policy in the EU:

The Moral Hazard of the Security of External Supply

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Swedish Institute for European Policy Studies

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FOREWORD

The European Union imports more than fifty percent of its energy consumption and growing energy demand implies that Europe's energy import dependency is increasing rapidly. The bulk of the energy imports originate from unstable regions and suppliers entailing major political and economic risks. The recent energy supply crises have inflamed the European debate on the security of energy supply.

The European Commission has proposed a common energy policy conducted in a spirit of solidarity among Member States as an instrument to address the issue of energy security. The authors of this report, Chloé Le Coq and Elena Paltseva, highlight that such a common energy policy may entail biased economic incentives and thereby cause problems with so-called moral hazard. Moral hazard arises because the Member States do not bear the full cost of their own risky energy consumption. Therefore, the Member States may have a tendency to increase the consumption of risky energy, which could increase the risk exposure of the European Union.

The authors stress that there is a need to establish a strong regulatory energy agency to coordinate the energy decisions of the Union and to solve the problems that are related to a common energy policy. They also discuss the benefits of integrating all energy policy issues into one single agreement and achieving more equal allocation of decision power within the Union. In addition, they provide a set of new indexes that measure the risks associated with the external supply of gas, oil and coal for each Member State.

SIEPS conducts and promotes research and analyses of European policy issues within the disciplines of political science, law, and economics. SIEPS strives to act as a link between the academic world and policymakers at various levels. This report is unique in bringing the moral hazard mechanism into the context of energy policy. By issuing this report SIEPS hopes to make a contribution to both academic and popular debate on a European common energy policy and the security of external supply.

Stockholm, February 2008

Jörgen Hettne
Acting Director

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EXECUTIVE SUMMARY

In the Green Paper "Secure, Competitive and Sustainable Energy for Europe" from March 2006, the European Commission defined three main objectives to be achieved by a Common Energy Policy: competitiveness of energy supply that would yield a "reasonable" energy price, security of supply ensuring energy availability, and sustainability, accounting for environmental constraints.

One of these objectives, the security of energy supply, has received particular attention in recent years. The EU imports more than 50% of its energy consumption and growing energy demand implies that import dependence will increase rapidly over time. Many of the energy imports originate from unstable regions and suppliers, putting European countries under serious risk. The recent energy supply crises caused by the Russian-Ukrainian and Russian-Belorussian conflicts resulting in some supply disruption further highlighted the need to enhance the security of energy supply within the EU.

Different tools to improve the security of supply have been discussed by policy-makers. Some tools focus on the demand side, aiming at a reduction in energy consumption whenever a country's exposure to the risky energy is considered too large. Other tools regulate the energy supply by, for example, imposing the "right" energy mix - the share of coal, nuclear, gas or renewable energies - to ensure a diversified energy portfolio. The relationship between Member States and external suppliers, such as the terms of the contractual arrangements and price negotiations, could be another tool of the common energy policy.

These ideas and tools for a European common energy policy have been frequently debated and profoundly analyzed in various studies. However, the bulk of the studies seem to address the issue of the security of energy supply from the political perspective, or focus on regulating internal energy markets. In this study, we demonstrate how a common energy policy might provide the wrong economic incentives and create a so-called moral hazard problem, undermining the security of supply and resulting in inefficient energy consumption. The moral hazard mechanism is well known in economic literature, but has rarely been discussed within the context of energy policy. To our knowledge, this study is the first to provide a formal analysis of this mechanism applied to the European common energy policy.

Approach. We focus our attention on the security of external supply, that is, supply provided by other parties to the members of the EU. We also concentrate on a particular aspect of the common energy policy, namely the principle of mutual insurance, also referred to as “solidarity” among Member States by the European Commission (2006b, p.8). A common view is that solidarity will benefit the Member States by improving the security of energy supply. In other words, countries within the Union may choose to compensate each other when there are supply disruptions, which would smoothen the energy consumption and thus increase welfare. However, a common energy policy involving mutual insurance against supply shocks may create a moral hazard problem. Mutual insurance allows the Member States to share the costs associated with their own risky energy consumption. Therefore it may induce members to increase their consumption of risky energy. This, in turn, increases the Union’s exposure to risk.

Purpose and main contributions. The objective of this report is to analyze the benefits of a common energy policy and the possible costs that "mutual insurance" may involve. The two main contributions of this report are: (i) an index that evaluates the risks associated with the external energy supply for each Member State and for three energy types (gas, oil and coal) (ii) a formal analysis of the potential moral hazard problem associated with a common energy policy based on solidarity among Member States.

Outline. The report consists of two parts. The first part discusses the security of energy supply in Europe while the second part provides a formal analysis of costs and benefits faced by countries relying on the common energy policy, in particular on its solidarity aspect. The first two chapters give a general overview of the problem of the security of energy supply in Europe. Chapter 1 defines the key concepts of the security of supply and in particular the notion of risky suppliers directly linked to the notion of supply disruption. Chapter 2 provides a brief overview of the debate on the security of supply in Europe and potential ways of addressing the problem of the security of supply. Chapter 3 presents an index that evaluates the risks associated with the countries' external energy supply. Our index is designed to access the short-run risk to the security of energy supply. The particularity of our approach is that we present a separate index for each energy type and classify European countries according to each index. Our index combines a net import dependency ratio with a proxy of the political risks existing in the supplying country and with a measure of risks of energy transport from the supplying country to the consuming country. Using IEA data from 2006, we construct the indexes for our sample of eighteen European countries and for three basic energy types: oil, gas and coal. Most other studies propose an aggregate index of the security of supply that combines different types of energy. We find that the EU countries' exposure to risks is not the same for different energy types. This implies that an aggregate energy security index may be somewhat misleading at least as regards the discussion of the short-term response to risks. Relying on an aggregate risk index without controlling for its composition may be a costly simplification since it is not possible to substitute different energy types in the short run. Poland, for example, has relatively high risk index for the supply of oil and a relatively low index for the supply of gas while the situation is the reverse for Portugal. Poland is therefore more likely to face an oil supply disruption than Portugal while the opposite holds true as regards a gas supply disruption. With our index we are able to evaluate the potential damage caused by a supply disruption in a specific energy market in a specific country. This would not be possible with an aggregate index that estimates an average risk of an energy supply disruption.

The second part of this report provides a formal analysis of the potential moral hazard problem associated with a common energy policy based on solidarity in terms of mutual insurance between members. We provide both a non-technical summary (Chapter 4) and a more rigorous treatment (Chapter 5) of our model. Our modelling framework allows us to relate the intensity of the moral hazard problem to the degree of policy coordination within the union, and to study the implications of moral hazard for the energy consumption and solidarity among member countries. More specifically, we analyze the choices of countries consuming energy from safe and risky sources. The countries can either operate in an autarky or form a union. If they form a union, they are subject to the common energy policy via a mutual insurance agreement. In other words, in a union, the countries at least partly insure each other against possible supply disruptions by redistributing the energy from a non-affected partner to the affected one. Three different regimes are considered. In an *autarky* there is no mutual insurance and countries take independent decisions. In a *coordinated union* the countries aim at maximizing its joint welfare, coordinating all the decisions (including the risky energy consumption and the level of mutual insurance). In an *uncoordinated union* countries insure each other against supplier default risk; however, countries make their energy consumption decisions separately, and do not internalize the effects these may have on the other country. Such formalization makes it possible to compare risky consumption, mutual insurance and welfare outcomes under the three regimes. The cost-benefit analysis depends on the type of coordination between union members, the degree of symmetry between countries, the agenda setter of the policy, and the possibility of redistribution among member states.

The results show that if countries are perfectly coordinated, the moral hazard problem does not arise. Therefore such a union outperforms the autarky due to the mutual insurance. However, whether each country is better off depends on the degree of asymmetry in the union. If the countries are identical, they both gain from forming the union, but if the asymmetry is sufficiently strong, one of the countries may end up being worse off than under an autarky. The reason is that providing mutual insurance is costly; the higher the probability of a supply disruption faced by the other members the higher the cost for a specific country. When countries face different probabilities of default, the mutual insurance can become very costly. A union will exist if there are transfers from the winners to the losers, or additional benefits associated with union membership. In an uncoordinated union the insurance opportunity creates a free-riding incentive that leads to an overconsumption of risky energy. The member who has leverage over the energy policy, tries to lower its increased exposure to risk by adjusting the mutual insurance rule. This amplifies the inefficiency and lowers the welfare as compared to the outcome of the coordinated union, but can reduce the risky energy consumption. Whether or not all union members gain in the uncoordinated union again depends on the countries' asymmetry, but in the presence of side payments an uncoordinated union improves upon the autarky. However, the coordinated union's level of welfare dominates.

Given these predictions, we address the issue of union formation, in particular, the incentives for a country to join the union even though it is costly to do so. We discuss the cases of additional benefits associated with union membership and the costs of staying outside the union. We also relate the allocation of power within the union to union stability and performance.

Summary of the results and policy implications. There are several policy implications based on the main results of the report.

First, the report proposes a set of new indexes measuring the risks associated with the external supply of different energy types (gas, oil and coal). We find that the risk exposure and risk ranking among the EU members differ for different energy types. This suggests that an approach based on estimates of risk by energy type i.e., a sectoral approach to the common energy policy would provide a more reliable base for quantifying the short-term external energy risks. Moreover, since the energy risks of countries may vary among different energy types, supply security may require different policy tools for each energy type, which again can be determined only with the help of a sectoral approach.

Second, the welfare analysis in the model suggests that the free-riding problem occurs when countries are not perfectly coordinated and can be very costly for the Member States. This implies that there is a need for establishing a strong regulatory energy agency to solve the moral hazard problem associated with a common energy policy based on solidarity between Member States.

Third, we demonstrate that the risky energy exposure does not need to be correlated with the efficiency. Despite the absence of moral hazard, member countries may consume more risky energy in the presence of such a coordinating agency. The uncoordinated union, led by the more influential member, might end up with a relatively low risky energy consumption. For example, when the leading country faces much smaller risks than the other union member, it may choose low mutual insurance coverage to avoid the moral hazard costs. This, in turn, decreases the risky energy consumption of both countries. However, such level is still inefficient as countries consume too much of expensive safe energy and have too little of mutual insurance. This implies that one should be cautious when using the level of risky energy consumption as a measure of the union performance as it is commonly done to discuss the security of supply issue. While being very reliable for a cross-country comparison at each given point in time, in the over-time perspective it may reflect not only risk exposure but also the institutional changes in the union. Therefore,

(i) in quantifying the security of energy supply, especially its development over time, one should take institutional developments within the union into consideration rather than rely on pure quantitative supply measures;

(ii) a common energy policy aimed at the security of energy supply should not necessarily require less consumption from the risky sources, as long as it improves the coordination between the parties involved.

Finally, we argue that when certain union members have more influence over energy policy decisions than the remaining members, it shifts the benefits of mutual insurance towards the more influential group. One way to achieve a more fair distribution of gains within the union would be to have the possibility of separate agreements on different energy policy issues. In this case the less influential members could choose to participate only in those agreements that benefit them, which would put a limit on the power of an agenda setter. However, a better way would be to integrate the energy policy issues, at the same time ensuring more equal allocation of the energy policy setting power among the Member States. This would benefit the EU both through achieving more efficient outcomes and improving the stability of the Union. The attempts to abuse the agenda setting power in one issue will be prevented by the threat of a punishment in the other energy issues, which will lead to more cooperative behaviour. Therefore, an integrated union with dispersed agenda setting power is likely to outperform the set of separate unions each covering single energy issue.

Part I

INTRODUCTION

Since the establishment of the European Coal and Steel Community (ECSC) in July 1952 there exists the view that European countries would be better off if they managed to create a supranational institution to help them coordinate on different issues, in particular energy issues. In the Green Paper "Secure, Competitive and Sustainable Energy for Europe" from March 2006, the European Commission has stimulated a new debate on the priorities of a common energy policy for the European Union. It emphasizes three objectives of a European energy policy: competitiveness, the security and sustainability of energy supply. Competitiveness of supply would imply a reasonable energy price, the security of supply would ensure the availability of energy, and sustainability would take environmental constraints into account.

In this report, we concentrate on the security of energy supply issue. We intentionally abstract from the European energy policy complexity, which allows us to provide a more detailed analysis of the security issue. Moreover, we focus on the external energy supply, i.e., the energy that comes from outside the EU. Part of this report is devoted to assessing the current state of the security of energy supply within the EU. We provide an index that evaluates the risks associated with the external energy supply for each EU member and for different energy types. In the second part of the report we use a stylized model of the EU to discuss the costs and benefits of a common energy policy aimed at improving the security of energy supply. We show how a common energy policy may distort economic incentives of the Member States and create a so-called moral hazard problem.

The security of energy supply has received particular attention in recent years. European countries purchase more than 50% of their energy from the outside sources. Since the demand for energy is growing in the EU, the dependence on foreign suppliers will increase rapidly over time. Many of the energy imports originate from unstable regions and suppliers associated with a substantial risk of supply disruption, which puts European countries under serious pressure.

The recent energy supply crises caused by the Russian-Ukrainian and Russian-Belorussian conflicts resulting in some disruption of supply stressed the need for creating a coordinated EU energy policy aimed at achieving the security of energy supply.

The security of external supply can be enhanced through a range of policy tools available at the European level and actively discussed by policy-makers. Some tools focus on the demand side, e.g. aiming at reducing the consumption of energy whenever a country's exposure to risky energy is considered too large. Other tools impose rules on the supply of energy by, for example, prescribing the "right" energy mix - the share of coal, nuclear, gas or renewable energies - to ensure a diversified energy portfolio. Energy security may also be improved by diversifying the energy suppliers or by revising the relationship between the Member States and external suppliers, such as the terms of the contractual arrangements and price negotiations.[1]

In this study we focus on one particular tool to improve the security of energy supply within the EU - the solidarity among the Member States. The solidarity is considered to be an important mechanism to address the problems of a sudden energy supply crisis. In the Presidency Conclusions (March 2007) the European Council stresses the need to enhance security of supply by developing more effective crisis response mechanisms, on the basis of mutual cooperation.[2] Member States are characterized by different energy portfolios and are therefore exposed to different risks of supply default. Hence, cooperation and mutual assistance may strongly improve the security of their energy supply. However, mutual cooperation may have its downsides.

In this report we address the potential moral hazard problem created by a common energy policy involving mutual insurance against random supply disruptions. In other words, we argue that while mutual insurance would indeed smoothen the energy supply shocks within the Union, it might induce members to increase their consumption of risky energy. This, in turn, would increase the Union's exposure

[1] See e.g. De Jong et al. (2007) or European Commission, (2007a) for more detailed discussion.

[2] Presidency Conclusions (March 2007), p.18

to risk, which could, in some situations, lead to a loss for individual members as compared to a scenario without a common energy policy. While the moral hazard mechanism is well known in economic literature, it has been rarely discussed within the context of energy policy. To our knowledge, this study is the first to provide a formal analysis of this mechanism applied to the European common energy policy.

The report consists of two main parts: Part II discusses the security of energy supply in Europe and Part III presents the formalization of the moral hazard problem associated with the common energy policy mentioned above. The first two chapters give a general overview of the problem of the security of energy supply in Europe. Chapter 1 defines the key concepts of the security of supply and in particular the notion of a risky supplier directly linked with the notion of supply disruption. Chapter 2 provides a brief overview of the debate of the security of supply issues at the European level and potential ways of addressing the problem. Chapter 3 discusses different approaches used to quantify the security of energy supply and suggests a new measure for the supply security for the European Union. For different energy types (gas, oil or coal) we provide an index of the short-term risk of supply disruption for most of the Member States. To do so, we combine the net import dependency ratio with the political risk and the measure of risk of energy transport between the supplying and the consuming countries. For each energy type we obtain a relative ranking of the risk exposure that every Member State faces when it purchases energy from outside its domestic market. The ranking varies between energy types since different Member States have different energy portfolios and therefore a different risk exposure.

We then proceed to the formal analysis of the positive and negative effects of adopting a common energy policy based on solidarity between Member States in case of an energy supply disruption. We use a stylized model of the EU that is simplified to encompass only the necessary features to capture the mechanisms we want to analyze. We concentrate on the mutual insurance mechanism and associated moral hazard problem, providing both a non-technical summary (chapter 4) and a more rigorous treatment (chapter 5) of our model. We show that the cost-benefit analysis of the policy depends on the extent of coordination between individual union members, the degree of symmetry between countries, the identity of the policy agenda setter, and the institutional possibility of financial transfers between member countries. We also address the issue of union formation, and relate the allocation of power within the union to the union stability and performance.

Finally, Part IV presents some policy implications of our study. First of all, we demonstrate that the risk of exposure for each Member State (and therefore the benefit of the mutual insurance) varies for different energy types. Therefore a common energy policy, or at least its aspects concerning the short-term response to the random supply disruptions would strongly benefit from a sectoral, i.e., according to energy type, approach. We also argue that Europe would need a strong regulatory energy agency to solve the moral hazard problem associated with a common energy policy based on solidarity between Member States. Interestingly it might be the case that the "optimal" risky energy consumption level could be higher with such an agency. The reason is the following. Assume that one of the Member States faces a high risk of supply disruption. Then the mutual insurance might be very costly for the other Member State. If the latter country is the one deciding on the percentage of losses covered by the union, it will choose a low coverage compared to the one maximizing the joint welfare. This low level of mutual insurance would make all Member States reduce their consumption of risky energy. Hence it might be the case that uncoordinated union with a leading country facing a comparatively low default risk might end up with a lower level of risky energy consumption than the one in coordinated union. This implies that one should be cautious when using the level of risky energy consumption as a measure of the EU's performance as it is commonly done to discuss the security of supply issue. While being very reliable for a cross-country comparison at each given point in time, in the over-time perspective it may reflect not only risk exposure but also the institutional changes in the Union. Therefore, one needs to control for the institutional adjustments when discussing the evolution of risky energy consumption over time. Finally we discuss the costs of having some member countries keeping a long-lasting leverage over the decisions on the common energy policy. It appears that Europe could benefit from more equal allocation of the agenda setting power on different energy issues among the member countries. In this case a union encompassing different energy issues may limit the selfish behavior of each agenda setter due to the potential punishment in the other energy issues. Therefore, such an integrated union is likely to induce more cooperative behavior and to outperform the set of separate unions each covering single energy issue.

We conclude this report by suggesting potential extensions of our modelling setup.

Part II

THE SECURITY OF ENERGY SUPPLY IN EUROPE

The security of energy supply in the European Union has been on the political agenda for some time. Recently, increasing dependence on energy imports, often originating from politically unstable regions and countries, intensified the discussion on the security of energy supply and made it one of the key concerns for EU policy. In this part we introduce the basic concepts used in the security supply debate, summarize the current view on the security of supply in Europe, and provide a quantitative assessment of the risks associated with the external energy supply in the European Union.

1 KEY CONCEPTS

1.1 The security of supply

Egenhofer & Legge (2001) broadly define the security of supply "as a variety of approaches aimed at insuring against supply risks". In this report we restrict our attention to the interpretation of the security of supply as a guarantee that all the energy volumes demanded will be available at a reasonable price. This corresponds to the definition used by the European Commission which states:

> "Energy supply security must be geared to ensuring [...] the proper functioning of the economy, the uninterrupted physical availability [...] at a price which is affordable [...] while respecting environmental concerns.[...] Security of supply does not seek to maximize energy self-sufficiency or to minimize dependence, but aims to reduce the risks linked to such dependence" (European Commission, 2000, p. 2).

The notion of security of supply includes security of "internal" supply and security of "external" supply. A security of internal supply is ensured when demand and supply are in balance in the domestic market at a reasonable price. A security of external supply is ensured if there is no interruption of energy supplied by the producers from outside the Union. In this report we focus on the notion of the security of external supply.

1.2 The notion of risk

As mentioned above the security of energy supply is associated with the continuity of energy supplies. Therefore the risk that we address in the report is the risk of an event affecting supply. More precisely, we focus on the disruption risk and not the price risk that can be associated with the security of supply.

There could be different reasons for energy supply disruptions. Van der Linde et al. (2004) list several of them: "deliberate policy changes in producing countries or producer country organizations, prolonged inadequate investments levels in production, transportation and processing and distribution capacity and/or maintenance, macro-economic instability in producer countries, socio-political instability in producer countries and/or regions, regulatory instability in consumer countries, market failures and government failures". Since we concentrate on the external supply, we only address the risks associated with foreign suppliers. One important key in this case is the political dimension related to securing access to primary energy. The idea is that energy traded with outside partners involves not only economic rationale but also political objectives. Röller et al. (2007, p.13) point out that "government-controlled foreign monopolist may restrict output beyond what a monopolist may do, in order to extract political concessions. In this case, supply security is a concern". Indeed, when rationing (interruption of supply) occurs, the market, by increasing prices, can not solve this problem. Hence if the energy import largely comes from a single large player in the market, it may cause concerns for the security of external supply. This dependence is not very problematic if the trading partner restricts output only according to economic rationales (for example, in order to raise prices). However, when this is not the case, i.e., when political pressure influences the seller's economic decisions, such a trading partner is viewed as a "risky" supplier. In other words, a contract with a "risky" producer leads to a high probability of energy supply interruption. It also needs to be mentioned that the aim of this report is not to isolate the causes of the disruptions of supply but more to analyze the potential reaction(s) of the recipient countries towards these disruptions.

There are different types of supply disruptions: short-term vs. long-term disruption, systemic (for the entire market) or specific risk, exogenous or endogenous to the consumer country, contractible or not, etc. Obviously different kinds of disruption may have different consequences (Luciani, 2004). In this report we concentrate on the risk associated with the short-term, exogenous, specific and non-contractible disruption of supply. The risk we consider is a short-term one since we are studying the case of a sudden disruption in supply that cannot immediately be accommodated by the market due to a lack of flexibility. It is exogenous since we assume that the consumer country cannot affect the probability of disruption. Finally, the risk is specific since it is associated with one particular energy supplier. Below we also address the vulnerability of EU Member States to such risks by constructing a measure of the security of energy supply in the EU.

2 The security of supply in the current European debate

The security of supply is one of the three main dimensions of European energy policy, together with environmental objectives and economic competitiveness. It has been a recurrent concern for Europe at least since the oil crisis in the 1970s. Moreover the debate on it has become fairly heated in recent years. At least two recent events have brought concerns about the security of supply in the headlines, putting pressure on the policy makers. First, in 2006 Russia decided to suspend gas deliveries to Ukraine and this resulted in a shortfall of 100 million tons of gas undersupplied to Western Europe. The same happened for oil deliveries via Belarus in January 2007, when the pipeline with a capacity of 50 million tons of oil was shut down.

So far Europe has succeeded in building a fairly strong internal energy policy. This policy focused on electricity and gas, imposing the same norms/obligations/market design for all European electricity and gas markets. The idea was to create a single, integrated European energy market. This was implemented through the Directive for Internal Market for Electricity (1996) and the Directive for Internal Market for Natural Gas (1998). However it becomes increasingly obvious that a common "external" energy policy is needed. The demand for energy and consequently energy prices have increased substantially over the last few decades and are predicted to increase even more. As a result, the concept of an "affordable price", a crucial component of the security of energy supply becomes increasingly eroded. In addition, it is likely that Europe will increase its energy imports from non-European suppliers. This leads to further discussions about necessary measures to be taken to ensure stability in the energy markets.[3]

Example: the supply of gas. The case of the gas supply in Europe is a good example to illustrate the problem of the security of external supply. The major gas suppliers of the EU have a monopoly position in their domestic markets and are controlled by their states. This implies that the supply from these companies may be heavily based on political motives. In other words, there is a risk of interruption in the supply of gas that may result from political considerations/events that are completely unrelated to the market conditions. GazProm is the most important gas supplier in Europe. Trading with GazProm can be considered risky because: (i) GazProm is not a fully independent company since there are strong ties between GazProm and the Russian Government, (ii) any delivery of Russian gas to Europe

[3]See van der Linde (2007) for an historical review of the energy policy in the EU.

Table 1. Largest Gas Suppiers of European Union

Country	%	Main exporting company	State ownership
Norway	17	Statoil	70
Russia	29	OAO GazProm	50
Algeria	13	Sonatrach	100
Nigeria	1	BBOC	100
Qatar	1	Qatargas	65

Source: Röller et. al. (2007)

has to go through (and be accepted by) a third country. It is beyond the scope of this report to give a precise measure of the risk level of GazProm as a gas supplier.[4] Here we only argue that such a supplier can be viewed as a risky supplier.

It is also important to mention that European countries depend on Russian gas to a varying extent. Spain, Portugal, the Netherlands, Belgium, Denmark and Sweden do not import Russian gas. The United Kingdom makes occasional purchases. On the other hand, Germany, Finland, France, Poland and other Member States regularly purchase Russian gas. Hence GazProm can be viewed as a risky supplier for some of the European countries but not for all of them.

The contribution of the EU. The common understanding is that the European Union may contribute to solving the problems of external energy security through several channels including the following:

1. *Solidarity.* The Green Paper explicitly mentions solidarity as a way of dealing with the consequences of any energy supply disruption, whether it is due to internal causes (like damaged infrastructure) or external cause (gas supply disruption). Solidarity among the Member States could allow the redistribution of energy between the members in the case of shocks. The EU would then be able to provide a mutual insurance among Member States.[5]

[4]See Hedenskog and Larsson (2007) for the relevant discussion.

[5]"With respect to the physical security of infrastructure, two main actions merit

Table 2. Share of Russian Gas in Total Consumption of Selected EU Countries

Country	Import	Russian gas import/Consumption
	Bem	%
Slovakia	7.5	100
Finland	4.5	100
Baltic	5.5	100
Greece	2.4	86.8
Czech. Rep	7.4	80.8
Austria	6.8	73.4
Hungary	9	63.4
Poland	7	50.2
Germany	36	36
France	13.2	26.8
Italy	22	26

Source: Finon and Locatelli (2007)

2. "*One voice*". The idea is that the EU should speak with one voice to the outside world. This harmonization would make the EU a stronger negotiator and reduce political interference in the economic market. The fact that Member States can pool their storage facilities may also affect the bargaining position vis-à-vis the energy supplier.[6] However, the amount of coordination that could be expected from European countries is an open question.

further consideration. Firstly, a mechanism could be developed to prepare for and ensure rapid solidarity and possible assistance to a country facing difficulties following damage to its essential infrastructure" (Green Paper, 2006, p.8). The Green paper also argues for a "... new legislative proposal concerning gas stocks to ensure that the EU can react to shorter term emergency gas supply disruptions in a manner that ensures solidarity between Member States, whilst taking account of the different potential for storage in different parts of the EU" (Green Paper, 2006, p.9).

[6] See, e.g. Helm (2005).

3. *Information effect.* The EU Member States can benefit from exchanging information about their energy contracts with external suppliers, such as the total contracted positions and terms of the contracts. This may potentially improve their position when negotiating with the suppliers.

In our formalization we focus on the first point, leaving the potential increased bargaining power and the information effect aside. We consider a particular mechanism of a common energy policy - the agreement of the members of the Union to provide assistance to a country facing supply disruptions by redistributing (some) of the unaffected energy supplies. We therefore ask whether a common energy policy, through solidarity among members, might improve the welfare of the Member States.[7] Obviously the European energy policy affects (inter)national actors, intra-governmental and non-governmental institutions and organizations. In this study, we consider the role of governments and therefore do not separately analyze the role and influence of these other participants on government policies.

3 Measuring the security of external energy supply in Europe

In this section we construct an index that evaluates the risk associated with a country's external energy supply and propose a classification of the European countries according to this index. The particularity of our approach is to present one index for each energy type. Given our focus on short-term risk exposure where substitutability among different energy types is not possible, an aggregate index that accounts for all energy types together may not be appropriate.

We start with an overview of the existing approaches to measuring

[7]Note that it is compulsory for the EU Member States to maintain strategic reserves equivalent to 90 days of domestic oil consumption. One can therefore argue that the solidarity among the Member States would not make much sence, at least for the oil. However, it is not clear whether these reserve requirements would suffice to cover any supply disruption that a country might face. Moreover, holding strategic reserves is costly. Therefore, solidarity among EU Member States might be a cheaper alternative to ensure the security of external energy supply.

energy security. Then we address the methodology and the data used to construct our index. We proceed by presenting the indexes obtained for the sample of eighteen European countries and three basic energy types: oil, gas and coal. We find that the EU countries' exposure to risks is not the same for different energy types. Finally, we discuss potential ways of improving and extending our methodology.

3.1 Approaches in the literature

The definition of the security of supply suggests that there are a number of country characteristics that could be used to measure the potential risks of the external energy supply. For example, Jansen et al. (2004) mention (i) net import dependency, that may additionally be weighted by the type and intensity of use of primary energy sources, (ii) the composition of energy imports by source of origin, (iii) the geopolitical stability of sources, (iv) allowance for resource depletion, (v) differences in energy demand and demand preferences, (vi) the degree of collaboration between nation states, (vii) transport distances and modes of imported energy resources, $(viii)$ and, finally, the marginal supply costs for each distinct energy source. A single energy security index cannot take all these factors into account. As a result, the literature describes several different ways of measuring the security of energy supply, and there is no clear consensus about a "correct" index. In this section we address some of these approaches.[8]

One of the most common ways to quantify the security of external energy supply is to measure it by looking at the *import dependency.* Due to their simplicity, these measures are often used in a general discussion about energy security or serve as a component of more complex energy security indexes that account for both internal and external security. For example, De Jong et al. (2007) construct a "Crisis Capability Index", by which they aim to quantify the potential impact of a sudden energy supply interruptions for a country, and the capability of that country to manage and mitigate these impacts. In this index they account for the security of external supply by using

[8] See Jansen, Arkel and Boots (2004) or Blyth and Lefevre (2004) for a review of the methodology.

the share of imports of different types of energy in the total energy imports. They weight these imports by their own assessment of risk associated with each energy type. To complete the index, they combine this resulting measure of external energy security with similar measures of the stability of the internal energy supply and energy transportation system.

This measure of external security ignores the extent of importance of energy imports for domestic consumption. Röller et al. (2007) account for this aspect of energy security by suggesting an *import dependency index,* calculated as the ratio of the energy net imports to the total energy consumption. They further combine this index with a measure of "operating reliability" given by the percentage of installed capacity in excess of peak load electricity demand. As a result, they construct a general energy security index where both the external energy supply (measured by the import dependency index) and the internal energy supply (measured by the power system capacity) are taken into account. De Jong et al.(2007) use a similar approach towards measuring external risks in their *long-term* Supply/Demand index. There they further subdivide the imports by the source (EU/non-EU) to account for different risks associated with different suppliers and use a complicated methodology to assess the "security" of the contracts. On top of import risks, this index also accounts for the demand side as well as energy conversion and transport.

The problem with the import dependency index calculated as a ratio of total energy imports to the energy consumption is that it does not account for the diversity of the energy suppliers that contribute to these imports. Obviously, the diversification/concentration of the suppliers may be crucial for the security of external energy supply. It can be captured in several ways, and the energy literature mainly relies on the two methodologies we address below.

The *Shannon-Wiener concentration index* measures diversity by multiplying the market share for each participant by the log of the market share and summing up the absolute values of resulting products over all the market participants. A higher value of the index means a lower concentration and the minimum value for the index is achieved when there is only one supplier. This index puts weight on the impact of smaller participants. The argument for using this index for the energy market is that it is the smaller suppliers that provide the options for potential switching between energy sources. The *Herfindahl-Hirschman concentration index* equals the sum of the squares of each participant's market share. More concentrated markets are characterized by a higher value of the index and the maximum is achieved when there is only one supplier. This index places extra emphasis on the contributions of participants with the largest shares. The logic behind applying this index as the measure of the security of external energy supply is that the foreign suppliers that constitute the larger share of domestic energy consumption may potentially also cause more problems to energy security.

These indexes seem to capture more of the underlying complexity of the energy security than the import dependency indexes. However, they are clearly incomplete and, thus, are normally extended by further factors to provide a more precise measure of the security of external energy supply. For example, Neumann (2004 and 2007) adjusts the Shannon-Wiener index by taking into account the indigenous production of the export country and the political stability of the import supplier country. Blyth and Lefevre (2004) use the Herfindahl-Hirschman index focusing on the energy supplier characteristics and the availability of the fuel supply in the supplier country. They argue that the market for each country is determined by all potential foreign suppliers and by their *potential* exports (production minus consumption). For each fuel they calculate the market shares of each supplier in that market. Then they combine the resulting Herfindahl-Hirschman index with a political risk rating associated with the supplier country and a measure of the market liquidity (given by the ratio of the total supply available on the market divided by the consumption).

3.2 Methodology and data

We aim at providing a measure of short-term energy risks associated with the external security of supply for each EU Member State. We disaggregate the index for the different types of energy as we concentrate on the short-term response to risk and do not address the issue of substitutability between different energy types. Therefore such a disaggregation allows us to better reflect the specific risks for each energy type. In building our index we follow the general strategy described above. However, our approach has some important differences compared to the ones we mentioned in the previous section.

Methodology. We measure the diversification of the energy portfolio of each country using the Herfindahl-Hirschman index rather than the Shannon-Wiener index used by Neumann (2004, 2007). The Herfindahl-Hirschman index places emphasis on larger suppliers, and is thus, we believe, better suited to capture the risks associated with the nondiversified energy portfolios. To calculate the market shares for each foreign supplier[9] we take the ratio of net positive imports from this supplier to the total energy consumption in the country in question. This allows us to indirectly account for the indigenous production without introducing an additional term into the formula as is done in Neumann (2004). The logic behind using the net positive imports as a measure of risk is as follows: If the net imports from a supplier are negative, the country in question exports more energy to the supplier country than it receives from this supplier. Therefore in the case of a default from this supplier a consuming country may compensate for its losses by cutting the respective exports. We also believe that this measure provides a better account of risks than the Blyth and Lefevre (2004) measure based on *potential exports*. The reason is that the potential exports market of Blyth and Lefevre (2004) may not reflect the short-term threats in the *actual* energy market faced by the country in question. For example, consider a country with all its energy consumption coming from one single supplier, that is small on the market of *potential* exports. In this case a high risk associated with this supplier is quite detrimental to the country's energy security but it is not captured by the Blyth and Lefevre index. One could argue that their index is better suited for reflecting the possibility of substitution between different suppliers. However, in our index we mostly address a short-term adjustment to shocks in which case such a substitution may not be relevant.

[9] We only look at the supplying *countries* and not firms due to the non-availability of the data.

We also supplement this index by a measure of the political stability of the supplying country which proxies for the political risks associated with the energy supplies. Additionally, we take the distance between the consuming and the supplying countries into account. The idea here is that the distance can be viewed as the proxy for the ease of energy delivery from the supplier. A supplier country may be in a state of political conflict. In this case it is more likely that the consuming country will be affected if this conflict is taking place "on the path" of the transport of energy from the supplier to the consumer country. For example, in 2006 Russia decided to suspend gas deliveries to Ukraine which resulted in a shortfall of 100 million tons of gas undersupplied to Western Europe. So our distance measure allows us to proxy the number of transit countries that have to be passed through in order to provide the energy. Note that this measure is more relevant for the energy types that are (at least partially) supplied through networks or pipelines, such as gas and oil, and less relevant for coal. Therefore we are not including this measure in our coal index.

Finally, we quantify the importance of each energy type for the consuming country. In order to do so we multiply our index by the share of the respective fuel in total energy consumption of the considered country. This allows us to approximate the impact of a potential energy supply disruption on the country's economy.

We first calculate a *Risky External Energy Supply (REES) Index* for each Member State and each energy type considered (gas, oil and coal). As a result, for each fuel type f the REES index for country a is defined by the following equation:

$$REES_a^f = SF_a^f \sum_i \left(\frac{NPI_{ai}^f}{C_a^f} \right)^2 r_i d_{ia},$$

where SF_a^f is a share of fuel f in country a's total energy consumption, NPI_{ai}^f are the net positive imports of energy f from country i to country a,[10] C_a^f is the total consumption of fuel f of country a,

10

$$NPI_{ai}^f = \max\left\{0,\ M_{ai}^f - X_{ai}^f\right\}$$

r_i is the political risk index of the supplier country and d_{ia} is some measure of a distance between countries i and a This index gives an estimate of how much external security energy supply matters for each country. Note that it decreases with the number of suppliers and the proximity of the consuming and supplying countries and increases with political risks.

The second index measures the contribution of each Member State to the risk that the EU is facing due to external energy supply. We believe that the problems faced by large EU countries have a greater impact on the EU energy security than the problems of the smaller EU members. We approximate the degree of influence of each country on the EU risk by this country's share in total EU imports. Then we construct the *Contribution to EU Risk Exposure (CERE) index* that measures the relative impact of each Member State on the aggregate EU risk. It is calculated as the REES index multiplied by the share in EU imports over the sum of these products for all Member States

$$CERE_a^f = \frac{REES_a^f * Share_a^f}{\sum_{j \in EU}\left(REES_j^f * Share_j^f\right)},$$

where $Share_j^f$ corresponds to the share of country j in net EU imports of fuel f.[11] As we will see, such adjustment might change the ranking of the EU Member States in terms of the external energy security.

Data. We construct our indexes for three main types of energy: oil, gas and coal. The data on the exports, imports and consumption for each energy type comes from the International Energy Agency. More precisely, we use the import volume, export volume, consumption level of crude oil, natural gas and hard coal, respectively. We

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where M_{ai}^f is the import of energy f from country i to the country a, and X_{ai}^f is the export of energy f from country a to country i.

[11]
$$Share_j^f = \sum_i NPI_{ji}^f \Big/ \left(M_{EU}^f - X_{EU}^f\right)$$

where $M_{EU}^f - X_{EU}^f$ measures the European Union's net import of fuel f.

Table 3a. Energy Profile of EU Member States: Gas

Country	Cons	Prod	Net M	Net M non-EU*	Share**
	Million M^3				%
Austria	8909	1819	7843	6177	41.6
Belgium	16467	0	16500	4300	37.4
Czech Republic	9325	169	9680	7249	21.8
Denmark	5060	10414	-5237	0	41.6
Finland	4750	0	4750	4750	30.4
France	44699	1208	44511	20568	33.4
Germany	100445	19609	82088	39405	35.7
Greece	3314	22	3295	3295	57.5
Hungary	14202	3095	11526	10562	26.6
Ireland	4697	510	4187	0	55.5
Italy	84484	10979	77030	58615	44.5
Netherlands	47804	77295	-29485	0	39.6
Poland	16336	5963	10876	10005	24.0
Portugal	4175	0	4200	4200	57.8
Slovak Republic	6575	123	6441	6940	20.8
Spain	33963	60	34409	32309	48.4
Sweden	976	0	976	0	28.4
United Kingdom	94404	83821	11165	3399	35.6

*) Net gas imports excluding imports from EU and Norway; **) Share of gas in total energy consumption. Source: International Energy Agency and Eurostat

also use the identity of the main supplier country(ies) that provided each of the energy commodities to the members of the EU in 2006. We were only able to obtain the complete set of data for eighteen EU members: Austria, Belgium, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, the Nether-

Table 3b. Energy Profile of EU Member States: Oil

Country	Cons	Prod	Net M	Net M, non-EU*	Share**
	Kt				%
Austria	8640	859	7698	7674	24.3
Belgium	31656	0	31553	25090	25.7
Czech Republic	8114	265	7725	7767	17.2
Denmark	7958	16753	-8786	-1096	22.5
Finland	10617	0	10441	7428	10.4
France	82909	1066	81821	60144	14.9
Germany	113428	3382	109099	74747	23.4
Greece	18804	83	18782	18782	7.5
Hungary	7098	886	6104	6104	43.3
Ireland	3233	0	3183	0	22.9
Italy	91989	5890	85964	82001	37.8
Netherlands	48038	1350	47065	38025	43.6
Poland	20452	792	19531	19494	13.0
Portugal	13478	0	13363	11296	14.1
Slovak Republic	5635	27	5528	5557	30.5
Spain	60933	139	60468	54783	20.8
Sweden	18791	0	19343	8423	1.6
United Kingdom	76804	69709	6742	4220	36.6

*) Net oil imports excluding imports from EU and Norway; **) Share of oil in total energy consumption. Source: International Energy Agency and Eurostat

lands, Poland, Portugal, the Slovak Republic, Spain, Sweden, the United Kingdom. However, we believe that these countries are sufficiently representative for the EU energy profile. The data on the share of each fuel in total energy consumption of each EU Member

Table 3c. Energy Profile of EU Member States: Coal

Country	**Cons**	**Prod**	**Net M**	**Net M, non-EU***	**Share****
	Kt				%
Austria	3884	0	4105	549	11.9
Belgium	8989	0	6978	7437	9.9
Czech Republic	22196	13747	-4734	-254	44.9
Denmark	9259	0	8447	7703	19.0
Finland	5694	0	6671	6105	14.3
France	18897	0	20251	17084	5.2
Germany	65379	23762	41062	29475	24.0
Greece	514	0	482	358	28.7
Hungary	1676	0	1755	871	11.1
Ireland	3036	0	2939	2574	17.8
Italy	24793	70	24634	24290	8.8
Netherlands	23060	0	13234	17210	10.1
Poland	113815	94405	-11455	2331	58.7
Portugal	6097	0	5777	5617	12.5
Slovak Republic	4817	0	4865	3085	22.1
Spain	34690	8353	23704	23590	14.4
Sweden	2873	0	3054	2477	5.1
United Kingdom	69352	17253	50926	49625	16.4

*) Net coal imports excluding imports from EU and Norway; **) Share of coal in total energy consumption. Source: International Energy Agency and Eurostat

State comes from Eurostat agency.[12] Tables 3a, 3b and 3c present the overview of the energy profile for the countries in our sample.

[12] We had to use the data from 2005, as 2006 data was not available. However the composition of energy portfolio of EU Member States is relatively stable over time, so we believe it does not have much impact on our indexes.

Our measure of political risks is based on the index produced by the PSR Group. The PSR Group's political risk rating assigns to the countries the values between 1 and 100, with higher values being associated with lower risk. We compute our risk measure as

$$r_i = \frac{100 - PSR\_Risk}{100},$$

so that higher values are associated with a higher political risk and the variable r_i is between 0 and 1.[13]

Finally, we construct a measure of distance as a proxy for the potential risks of energy transportation. We do not believe that the ease of delivery is linearly dependent on the actual geographical distance. That would put a disproportionately high weight on the suppliers furthest away. The safety of delivery falls the further away the suppliers are, but it does not decrease drastically with distance (as long as we account for associated political risks). Therefore, instead of using the geographical distance between the countries, we create a categorical distance variable: We classify all country pairs into 3 groups according to the distance between their capitals: under 1500 km, between 1500 and 4000 km and above 4000 km, with these groups being assigned a distance index of 1, 2 and 3 respectively

$$d_{ia} = \begin{cases} 1, \text{ if dist\_btw\_capitals} < 1500 \text{ km} \\ 2, \text{ if } 1500 \leq \text{dist\_btw\_capitals} < 4000 \text{ km} \\ 3, \text{ if dist\_btw\_capitals} \geq 4000 \text{ km} \end{cases}.$$

The idea behind choosing these thresholds is as follows: The European countries would not have much difficulty supplying energy to each other and they roughly belong to the first group. From that category on the index (weakly) increases with the distance between the supplying and consuming countries, but it takes greater and greater distance to fall into the next category.

[13] PSR Group has no data on the geopolitical risk for Turkmenistan and Uzbekistan. We approximate it by the risk associated with Kazakhstan, assuming that the Kazakhstan's index might reflect a regional risk.

3.3 Results

The results of our estimations are presented in Tables 4 and 5. We see that the countries' ranking based on both the REES and CERE indexes differs for different energy types. Also, the range of REES indexes differs between energies. We provide more details on that as we proceed to the discussion about the index for each energy type. Note also that the CERE indexes change the country risk ranking, moving larger countries up and smaller countries down the risk scale. This is due to the definition of the CERE index, since it is based on the counties' REES indexes weighted by the share of each respective country in the total EU imports. This reflects our belief that, other things being equal, countries, which are responsible for larger part of EU net imports, are also greater contributors to the overall EU external energy supply risk.

Gas indexes. Different EU Member States face different situations in the gas market: Some of them have substantial indigenous production, others obtain most of their imports from EU suppliers or Norway, while the third ones only purchase their gas from outside the EU/Norway area. Moreover, for some of the Member States natural gas constitutes a substantial share of their energy portfolio, while other Member States rely more on oil, coal or other fuel types (see Table 4). As a result, countries can be subdivided into three groups with respect to their REES index. The group with a relatively high index includes Austria, the Czech Republic, Hungary and the Slovak Republic. These countries do not produce any gas and usually import most of their gas from non-EU/Norway suppliers, which implies that both the distance and political risk factor contribute to a higher index value. The share of gas in their total energy consumption is relatively high. On top of that, some of these countries do not have well-diversified external gas supply. Finland, Germany, Greece, Italy, Ireland, Portugal and Spain constitute the group of medium risk, with better diversified gas imports and/or less reliance on gas in their aggregate energy portfolio. The remaining countries have a relatively low index either due to their indigenous production (like the Netherlands, or the United Kingdom) or to their mostly European import origin.

Table 4. REES Index (higher values correspond to higher risk)

Country		Natural Gas	Crude Oil	Hard Coal
Austria	AT	8.1	3.5	1.3
Belgium	BE	1.5	6.3	0.6
Czech Republic	CZ	7.3	7.1	0.0
Denmark	DK	0.0	0.6	1.3
Finland	FI	3.6	4.9	2.1
France	FR	0.9	1.7	0.2
Germany	DE	2.8	3.3	0.4
Greece	GR	3.6	10.6	3.1
Hungary	HU	12.9	16.9	0.8
Ireland	IE	3.4	4.7	1.4
Italy	IT	3.6	2.9	0.6
Netherlands	NL	0.0	5.6	1.0
Poland	PL	1.2	7.3	0.0
Portugal	PT	5.2	3.7	1.6
Slovak Republic	SK	23.5	14.0	2.5
Spain	ES	2.8	4.1	0.4
Sweden	SE	0.3	2.1	0.3
United Kingdom	UK	0.1	0.9	0.9
Average		4.5	5.6	1.0
Standard deviation		5.8	4.4	0.9

CERE gas ranking moves Germany and Italy up the scale, making them the most important contributors to EU risk exposure. This is a result of their gas consumption being relatively important at the EU level. However, smaller countries like Hungary and the Slovak Republic are still in the top risk group because they rely almost entirely on non-EU suppliers for their gas imports.

Table 5. CERE Index (higher values correspond to higher risk)

Country		Natural Gas	Crude Oil	Hard Coal
Austria	AT	5%	1%	3%
Belgium	BE	2%	5%	3%
Czech Republic	CZ	6%	1%	0%
Denmark	DK	0%	1%	6%
Finland	FI	1%	1%	8%
France	FR	3%	12%	2%
Germany	DE	21%	17%	10%
Greece	GR	1%	5%	1%
Hungary	HU	12%	1%	1%
Ireland	IE	1%	1%	2%
Italy	IT	22%	17%	9%
Netherlands	NL	0%	8%	10%
Poland	PL	1%	2%	0%
Portugal	PT	2%	3%	5%
Slovak Republic	SK	14%	1%	9%
Spain	ES	8%	13%	6%
Sweden	SE	0%	2%	1%
United Kingdom	UK	0%	8%	25%
Total, 18 EU members		100%	100%	100%

Oil indexes. The supply of oil to EU countries bears slightly more risk than gas, but the difference between the countries is lower. Indeed, the average value of the REES index increases from 4.5 to 5.6 between the gas and oil indexes and the standard deviation decreases from 5.8 to 4.4. This is mostly due to the two main reasons: first, the share of oil in Member States' energy consumption is higher on average than the share of gas. That suggests that a disruption of oil supply would be associated with higher costs, and thus cause higher risks to the economy. In the same time, oil market is more global than the gas market, implying that the difference in risks between EU Member States should be lower for the oil consumption. As Table 4 suggests, all EU members can be roughly subdivided into three groups. Greece, Hungary and the Slovak Republic represent the group of countries with the highest risk exposure. Neither of these three counties has a well-diversified oil supply. Hungary and Slovak Republic purchase most of their oil from a single and somewhat risky supplier, namely Russia. Greece oil imports come mostly from Russia, Iran and Saudi Arabia and its economy is heavily dependent on oil which increases the risk index. Then Belgium, the Netherlands, the Czech Republic and Poland constitute a middle risk group. The first two countries in this list have a somewhat more diversified oil import structure, while still consuming a most of their oil imports from a few relatively risky producers. The second two countries still purchase a sizable part of their imports from one or two risky supplier, but their economy does not heavily rely on oil as the primary energy source. Finally, the remaining countries have a relatively low external oil supply risk as measured by the REES index. This is due to more diversification and, in some cases (e.g. Denmark or the UK), noticeable domestic oil production.

As regards contribution to the EU's risk exposure represented by the CERE oil index, the countries at the top are mostly major oil importers (e.g. Germany or Italy), some of which also have a substantial share of oil in their energy portfolio.

Coal indexes. The security of coal supply is usually not considered to be a serious problem, because the world coal market is well diversified, many Member States have indigenous coal production and coal is easy to store. Indeed, the average coal REES index is much smaller than for gas or oil, and so is the difference in risk between the EU Member States, measured as a standard deviation of the index. Greece, Finland and the Slovak Republic have the highest REES index due to a poor diversification of suppliers, non-EU/Norway imports and no indigenous production. However when controlling for the relative share in the total EU imports through the CERE index, the United Kingdom, the Netherlands and Germany go to the top of the ranking list.

Table 6. Other Energy Security Indexes (higher values correspond to higher security)

Country	De Jong et al.	Röller et al.	Neumann		
	(1)	(2)	(3)		
			Gas	Coal	Oil
Austria	57	1.8			
Belgium	57	5.7			
Czech Republic	64	3.4			
Denmark	82	4.4			
Finland	53	5.1	1.3	1.2	1.6
France	64	4.4			
Germany	63	4.6	1.3	1.3	1.4
Greece	44	3.8			
Hungary	55	5.1			
Ireland	75	5.8			
Italy	50	4.5	1.3	1.0	1.3
Netherlands	69	4.8	3.3	0.8	1.5
Poland	60	1.6			
Portugal	47	4.5			
Slovak Republic	51	4.7			
Spain	51	4.2	1.1	1.2	1.5
Sweden	70	4.9			
United Kingdom	80	4.8	1.7	1.1	3.3

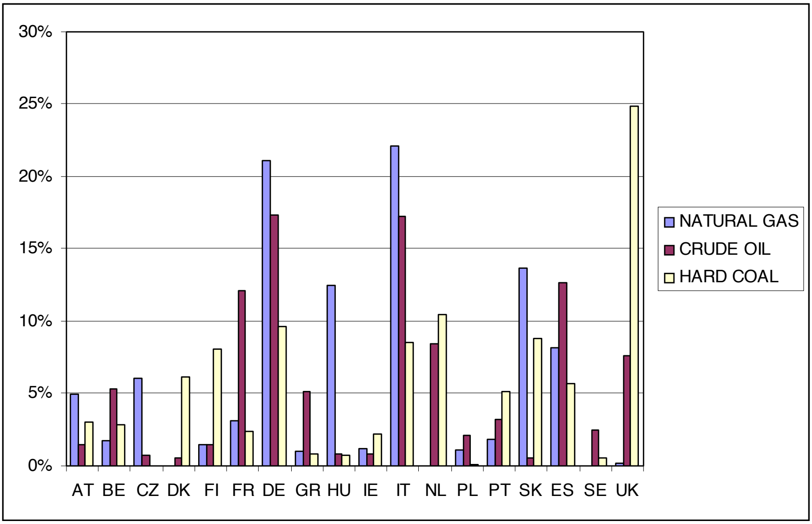
Source: (1) De Jong et al.(2007), Supply-Demand Energy Security Index, (2) Röller et al. (2007), Security of Supply Index, (3) Neumann (2007), Security of Supply Index

In Table 6 we also provide a summary of the three other energy security indexes: Röller et al. (2007), De Jong et al. (2007) and Neumann (2007). Note that it is only the Neumann index that is directly comparable to ours. The other two indexes do not concentrate on the external security of supply, as they also deal with other security aspects and aggregate measure over different energy types. Indeed, one can see that the first two indexes are not even mutually consistent: for example Poland is classified as a relatively secure energy consumer by Röller et al., while it has a rather risky position according to the De Jong et al. index. The reverse is true for Portugal. Our classification shows that Poland is exposed to more risks in the oil market (REES=7.3 for Poland vs. 3.7 for Portugal), while Portugal is more vulnerable in the gas market (REES =1.2 for Poland and 5.2 for Portugal). Therefore, the aggregation of different energy types may indeed lead to inconsistent results due to differences in methodologies.

The Neumann index is more consistent with our results. However, we believe that our index produces more precise classification of countries. For example, the Neumann index ranks Finland and Germany equally in the gas market. Our index suggests that Finland is more vulnerable to the risks of gas supply disruption than Germany. The same observation holds for the comparison of the Netherlands and Spain in the oil market - they have the same Neumann index, while our index suggests that Spain oil supply is less secure. We believe this distinction arises from two main differences between our and Neumann's approaches: first, our index is better suited to reflect the threat of badly diversified energy sources, second, it accounts for the importance of each fuel in the total energy portfolio.

As our discussion above suggests, the EU countries' exposure to risks is not the same for different energy types. This is easy to see in Figure 1, that plots the CERE index for different energies. This implies that an aggregate energy security index (provided for example by Röller et al. or De Jong et al.) may be somewhat misleading at least for the discussion of the short-term response to risks. In other words, in the short-term the substitutability among different energy types is problematic, and thus relying on an aggregate risk index without controlling for its composition may prove to be a costly simplification.

Figure 1. Contribution to EU Risk Exposure



3.4 Possible extensions and problems

Our methodology can be extended in several ways. First, our measure of the energy portfolio diversification is somewhat incomplete. For example, it does not address the technological aspect of energy supply. Gas can be transported through pipelines or as LNG, which also has implications for the way it can be stored. Clearly, the extent of diversification of energy supply with respect to technology may have an impact on the security of the supply and we do not account for it in our index. Second, our index does not account for the possibility of correlated energy shocks such as a correlation between different suppliers (e.g. due to certain natural disasters or political events) or a correlation of shocks to the supply of the same energy to different EU members (e.g. due to a reliance on the same pipeline). Taking these effects into account would, however, be difficult due to the lack of respective systematic data. Third, no environmental constraints are taken into account.

Our index deals with the short-term response to the energy shocks and thus provides a static measure of risk. It can be extended to a more long-term measure. In this case several more aspects should be taken into account. First, one needs to consider the possibility of substitutions between different energy types, addressing the issues of energy supply dependence across fuels. Second, the effect of change in energy demand should be included in the index. For example, the domestic consumption of many EU countries as well as supplying countries is predicted to rise, which may boost competition for the energy and change the availability and prices of the supply (Stern, 2006). Also, the competition may become more global, as it already tends to be for LNG gas between the EU, North America and the Pacific region, which might also affect energy security. Moreover, it is anticipated that the indigenous gas production of the EU Member States will stagnate, which again may have some impact on the security of supply. Finally, new sources of energy may also affect energy security.

Part III

FORMALIZATION OF THE MORAL HAZARD PROBLEM

In this section we provide a formal analysis of the costs and benefits faced by countries relying on a common energy policy, in particular on its solidarity aspect. A common view is that solidarity will benefit the member states by improving the security of energy supply. In other words, countries within the union may choose to compensate each other in case of supply disruption which would smoothen the energy consumption shocks and thus increase welfare. However, a common energy policy involving mutual insurance against supply shocks may create a moral hazard problem. Mutual insurance allows the member countries to share the costs associated with risky energy consumption while still fully enjoying the consumption benefits. Therefore it may induce members to increase their consumption of risky energy. This, in turn, would increase the union's exposure to risk. In some cases the effect would be sufficiently strong to make some union members worse off compared to being in an autarky (where no union is formed and thus there is no room for mutual insurance).

To analyze this problem we use a highly stylized model of the energy-related mutual insurance within the European Union. It is simplified to encompass only the necessary features to capture the mechanisms we are interested in. Making the model more complex would significantly complicate the analysis without adding much qualitative difference to the results. However, we address the validity of our simplifications and assumptions throughout the report and discuss their impact on the model predictions after presenting the main results.

The model we suggest is closely related to several areas in economic literature. First it draws on the classic aspects of an insurance-associated moral hazard originating from Arrow (1963). Moreover, as the problem involves mutual insurance, a moral hazard is created in the absence of informational asymmetries. Each country has an incentive to share the costs associated with supply disruption and the reciprocity within the union forces the countries to agree to cover a part of another party costs. As a result, this agreement results in free-riding within the union: each country has an incentive to over-consume risky energy.

The model also parallels some of the literature on fiscal federalism and the political economy of international unions (e.g. Besley and Coate (2003), Persson and Tabellini (1996), Alesina et al (2005) etc.) that studies the provision of local public goods. The arguments there suggest that if public goods within a union can be provided locally but have to be financed at the federal level, the economy faces a common pool problem. This means that each union member (or country's region) tends to overprovide public goods which results in an inefficient outcome. In our setting one might think of risky energy consumption as a local public good and of mutual insurance cost sharing as a union-wide financing of the public good provision.

In addition, there is a link between our model and the literature on the bank runs. This literature argues that an interconnected banking system would provide an insurance against local liquidity shocks, but may at the same time result in financial contagion (see e.g. Fecht and Grüner (2005)). Similar effects take place in our model.

However, to our knowledge these approaches have not yet been applied to the issues of security of energy supply, which is the key of our model. Our framework allows us to discuss the welfare impact of the introduction of a common energy policy. Additionally, our formal model yields results that we find important for quantifying the discussion on energy security. We show that one should be careful in relying on risky energy consumption as a measure of the security of supply, at least from the efficiency perspective. A common stance is that the moral hazard problem would imply the overconsumption of risky energy. However, we demonstrate that in some cases a more efficient (i.e., less subject to moral hazard) common energy policy may be associated with higher risky consumption. This implies that a) in quantifying the security of energy supply, especially its development over time, one should take into consideration institutional developments within the union rather than rely on pure quantitative supply measures; b) a common energy policy aimed at the security of energy supply should not necessarily require less consumption from risky sources, as long as it improves the coordination between the parties involved.

4 NON-TECHNICAL SUMMARY

4.1 The objective

This section presents the main conclusions of our formalization without the technical developments. We try to be as precise as possible but for a more careful analysis (especially in terms of comparative statics) we refer the reader to the model section.

In the previous sections we provided a general discussion about a common energy policy, explaining the different objectives and tools of such a policy. In our formalization we choose a more restrictive notion of common energy policy, focusing on the degree of solidarity between member states. In particular, by solidarity we mean that member states will redistribute energy among themselves if there is an interruption of supply. Such solidarity can be viewed as a mutual insurance between member states and the extent of mutual insurance (solidarity) is characterized by the amount of energy that a country agrees to transfer to another member country affected by a supply default.

Our purpose is to analyze the benefits of having a common energy policy and the possible costs that the mutual insurance may involve by providing the member countries with the wrong incentives and creating a moral hazard problem.

We focus on three types of union constellations associated with different solidarity rules. Our formalization allows us to discuss different issues related to the common energy policy, in particular:

- The level of risky consumption. How much risky energy consumption can we expect given the union constellation considered? Is energy consumption a good measure for the security of energy supply?
- The level of mutual insurance. Is the extent of mutual insurance correlated with the union constellation considered?
- The level of welfare. How do different constellations compare in terms of welfare?

4.2 The context

The energy market. We consider a market where each member state purchases a single type of energy (e.g. oil, gas etc.) from two suppliers, a "safe" one and a "risky" one. The "safe" energy supplier always delivers the exact contracted amount. The "risky" energy supplier may sometimes default on delivery. In other words, this supplier may fail to provide the contracted amount to the consumers even though the payment has been made. In section 3.2 above we describe the energy consumption profiles of the EU members. We show that every country purchases energy from a set of suppliers, each associated with its own degree of risk (measured by the political risk index and the distance between the supplier and the home country). Here we use a simplified interpretation with each country being exposed to one safe energy supplier (with no associated risk) and one risky energy supplier (associated with a positive risk of interruption of supply). The countries face the same risky energy price, because the energy comes from the same producer. However, they may face different prices for the safe energy. The intuition behind this is that countries may differ as regards the ease (and the price) of access to safe energy - some of them produce it domestically while others have to import from "safe" outside sources, such as other EU members etc. For each country the "risky" energy is cheaper than the "safe" energy, otherwise no risky energy would ever be consumed.

The security of energy supply for each member state. Each state aims to satisfy its energy consumption needs and lower the negative effects created by an energy supply disruption. Any supply failure requires adjustment costs that all countries want to minimize. That is, the welfare of each country is given by its targeted energy consumption less the costs of not meeting this target. A contract with the producer of "safe" energy provides a country with an insurance against default. At the same time, "safe" energy is more expensive. Therefore, in choosing its energy bundle, the country must decide whether it should buy an extra unit of safe energy that is more costly than a risky energy unit but might be needed in case of supply disruption.

Union constellations. Countries may choose to form a union with a common energy policy promoting solidarity among the member countries. We consider a particular type of solidarity: member countries agree to cover a share of the others' losses if there is a default. Clearly, this type of mutual insurance is at work if only one country faces a default. It lowers the default loss of the affected member at the expense of the other party.

We analyze three types of union constellations:(i) an *autarky*, (ii) an *uncoordinated union* and (iii) a *coordinated union.* A union constellation is characterized by the degree of solidarity between the member states (i.e., the percentage of losses covered by the non-affected party) and how such a degree is decided inside the union constellation. Hence, each union constellation has its own rules for a common energy policy.

An *autarky*, or degenerate union, is a constellation with no mutual insurance so that each country's decision (in terms of energy consumption) does not depend on the other country's default risk.

In a *coordinated union* (hereafter CU) there is perfect coordination among the member states and all the policy decisions (including the risky energy consumption and the level of mutual insurance) are chosen to benefit the entire union.

In an *uncoordinated union* (hereafter UU), countries also use the opportunity of mutual insurance provided by the union. However, they take their energy consumption decisions separately, not accounting for the effect on the other union members. In other words, they do not coordinate on the choice of the risky energy consumption. We assume that the degree of mutual insurance (the share of loss covered in case of default) is, in turn, decided by only one *leading* country. This assumption is a simplified way to capture the unequal distribution of power within the European Union, documented by several studies. For example, Tallberg (2007) argues that "negotiations on budgets, institutional reform, foreign policy, and other contentious dossiers, indicate that bargaining power in the European Council is unequally distributed" or that "the preferences of France, Germany, and the UK most often set the parameters of European Council negotiations." This argument can also be extrapolated on the issues of energy policy. For example, during the six months of German presidency in the European Union common energy policy was an important part of the political agenda, and Germany had a strong influence over the policy measures taken at the European level. On the other hand, Poland's 2006 proposals concerning common energy policy were rejected by major EU members such as Germany and France. However we also address the implications of relaxation of this assumption.

The timing. First, countries decide to form a union constellation with a specific common energy policy (or degree of solidarity). Then, given the chosen union constellation, they decide on their energy portfolio, that is, the consumption of safe and risky energy needed for their economies. In case only one country faces a supply default, the solidarity commitment implies that the other country covers part of the losses. Note that if both countries face a default, it is assumed

4.3 Results

4.3.1 Different effects at play

We discuss here the different effects that are at play in this formalization. We focus on energy consumption since it is directly linked to the potential moral hazard problem (or free-riding problem) created by a common energy policy involving mutual insurance against supply shocks. Since we argue that a union with a common energy policy would indeed reduce the impacts of energy supply disruptions, it might induce members to increase their consumption of risky energy. This, in turn, would increase the union's exposure to risk, which could, in some situations, lead to a loss for (a) member(s) compared to being in a union with no mutual insurance (an autarky). We start by describing the price and default risk effect as well as the free-riding problem assuming that the mutual insurance rule within the union is fixed, that is, we study *partial* effects of these variables. We then proceed by letting the mutual insurance rule vary. We investigate the effect of prices and default risks on choice of the mutual insurance rule and then take this effect into account in studying the *full* effect of prices and default risks on risky consumption and welfare.

Price and default risk effect given a mutual insurance. Assume first that the mutual insurance rule is given. Consider the effect of the safe energy price and the default probability effect on risky consumption.

Price (partial) effect. For a given redistribution rule cheaper (own) safe energy decreases risky energy consumption. This is a rather intuitive result: risky energy is not being supplied in the default state of nature, so it is only consumed in this economy because it is cheaper than the safe one. As the price of the risky energy becomes relatively more expensive, it is substituted by the safe energy in the consumption bundle.

Default Risk (partial) effect. There are four possible states of nature depending on the correlation between the defaults, and four corresponding probabilities. More precisely, each country distinguishes between a *safe state* when neither country faces a default, a *local default state* when a country is the only one facing a default, a *foreign default state* when the other country is the only one facing a default and the *double default state* when both countries are affected. As the sum of all four probabilities is one, the effect of a change in the probability of one of the states can be found as a linear combination of the other three effects. We concentrate on the change in the probabilities of the states when at least one country faces a default. More precisely, a *default probability* for a country is the sum of the *local default probability* and the *double default probability*. An increase in each of these two probabilities holding the other one fixed lowers the consumption of the risky energy since in both these states this country pays (at least part of) the costs of consuming risky energy. The higher each probability, the higher the associated cost and thus the lower the incentive to purchase risky energy is. So if an increase in the probability of default results from an increase in both components, it lowers the risky energy consumption of a country. However, the general relationship between the default probability and risky consumption is unclear. For example, an increase in the total default probability may be caused by an increase in the local default probability accompanied by a smaller decrease in the double default probability. In this case the effect on risky consumption is ambiguous.

The mutual insurance effect. Let us first consider an uncoordinated union. As with any mutual insurance problem, each country has an incentive to free-ride on the other union member. In our case free-riding leads to the overconsumption of risky energy. Moreover, the more mutual insurance there is, the stronger the free-riding incentive and the higher the consumption of the risky energy.

For a coordinated union the policy decision takes into account the potential free riding problem when deciding on the level of risky consumption. For low levels of coverage the cost imposed by the mutual insurance obligations is not too high so that more insurance induces higher risky energy consumption. However, as the mutual insurance coverage increases, so does the associated cost. To compensate for this the social planner reacts by lowering the level of risky consumption.

Table 7 summarizes the price and risk default partial effects and the mutual insurance effect on risky consumption.

Table 7. Partial Effects on the Risky Energy Consumption

Effects		**Risky consumption**		
		Autarky	**UU**	**CU**
Price (partial) effect	*Own safe price*	+	+	+
	Other safe price	0	0	0
Default risk (partial) effect	*Double default*	-	-	-
	Local default	-	-	-
	Foreign default	0	0	0
Mutual insurance effect	*Redistribution rule*	0 (by def.)	+	+/-

Optimal choice of mutual insurance. So far we have discussed the partial effects on risky consumption when the mutual insurance rule is given. We now turn to the determination of the mutual insurance rule (or more precisely the percentage of losses covered by the non-affected party) in different union constellations. Then we discuss the full effect of exogenous variables assuming that the redistribution rule may vary.

Optimal mutual insurance is the result of a trade-off between redistributing the cost of supply interruption and avoiding the moral hazard problem. For each country, the optimal mutual insurance choice is influenced by the response in its own as well as the other party's risky energy consumption. As a result, in a coordinated union the mutual insurance coverage is always set at 50%. As long as the cost of supply disruption increases more than proportionally to the amount of underprovided energy, two countries in the union are best off when the cost of disruption is equally split between the affected and non-affected members. Mutual insurance in an uncoordinated union can be above or below 50% depending on the asymmetry between the union members. However, if the members are exactly identical, the coverage rate set in an UU always falls short of the 50% rule of a coordinated union. This is due to the moral hazard incentive provided by the mutual insurance. Indeed, each country overconsumes risky energy as it does not account for the cost this consumption entails for the other union member(s). Therefore the leading country has to cut on the coverage rule to lower its costs of compensating the other country's default losses.

Full effects. Now let us turn to the full effect of the change in price or default probability on the risky consumption. Namely, we take into account the adjustment of the optimal insurance rule. In an autarky there is no mutual insurance, so obviously the full effect coincides with the partial effect. However, in the presence of mutual insurance the full effect is often ambiguous. For example, consider an UU where the leading country faces an increasing probability of foreign default. This increases the frequency of the states in which the leading country has to compensate the other country, which induces the leading country to choose a lower redistribution rule. Second, other things being equal, an increasing probability of default lowers the other country's consumption of risky energy. This implies lower costs for the leading country (partially) compensating the other country's default loss, while the leading country's gains from the mutual insurance stay the same. Thus the leading country's consumption in UU can be higher or lower as the probability of foreign default increases.

4.3.2 Welfare analysis

We provide a welfare analysis and compare the outcome between different constellations. We use the autarkic equilibrium, i.e., the absence of any common energy policy as a benchmark.

Autarky vs union. The results show that if countries are perfectly coordinated, the moral hazard problem does not arise. Therefore a perfectly coordinated union outperforms the autarky in terms of the aggregate welfare due to the possibility of sharing risks through the mutual insurance. Mutual insurance also benefits the members of an uncoordinated union. In particular, if the countries are completely symmetric, both of them achieve higher welfare in an uncoordinated union than in an autarky.

However providing mutual insurance is costly; the higher the probability of the others facing a supply disruption, the greater the cost for each specific country. Consider the situation when the countries are asymmetric (in terms of safe energy prices or the risk of default) and they are unable to compensate each other with transfers (which should be understood very broadly, and can include subsidies, exceptions to the common rules, etc.). In this case it is no longer evident that each member in a union gains as compared to an autarky. This might especially be the case for the uncoordinated union where the member with leverage over the energy policy tries to lower its own exposure to risk by adjusting the mutual insurance rule at the expense of the other party. With sufficiently high asymmetry, the union might become a burden for the less influential member country, making it worse off than it would be outside the union. For example, this might occur when the leading country faces a much higher supply disruption risk. In this case the “losing” country would only join the union if the union membership were associated with certain additional benefits. We discuss examples of such benefits in more detail below. Moreover, the uncoordinated union may be worse than an autarky even in terms of aggregate welfare, again, at the cost of its less influential member. However, when the bargaining power within the union is more equally distributed so that none of the members has a strong leadership, an uncoordinated union is likely to improve upon an autarky.

If the institutional structure of the union allows for transfers, all members of the coordinated union always achieve higher welfare than in the autarky. The reason is that the coordinated union may always compensate the "loser" by arranging a transfer from the "winner". Indeed, since the union maximizes the joint countries’ welfare, the sum of the two welfares in CU will be always higher than in autarky, which means that such a transfer will always be possible. In an uncoordinated union, when the leading country is "myopic", i.e. does not account for the possibility of transfers in setting the common energy policy, this is not always the case. As was mentioned above, this is due to the potential asymmetries as well as the free-riding problem arising in such constellation. If the leading country prefers much more insurance than the other member, it may distort the welfare so much that its own gains will not be enough to compensate for the loss of the other member. Again, such a union should provide some additional participation incentives which we address below. However, if the leading country in the UU takes the transfer possibility into account, it may always ensure an outcome that is at least as good as in an autarky for both parties.

Uncoordinated union vs. coordinated union. Now we turn to the comparative welfare analysis of a coordinated vs an uncoordinated union. In an uncoordinated union each country ignores the negative impact of an increase in its own "risky" energy consumption on the other member state welfare. Therefore the joint welfare is always lower in an uncoordinated union than in a coordinated one, suggesting that at least one country always loses in an uncoordinated union as compared to the socially optimal case of a coordinated union. Again, whether or not each country loses is unclear and depends on the asymmetry between the countries. Typically the country that sets the policy in an uncoordinated union loses less or even gains if the asymmetry is sufficiently high.

4.3.3 The risky energy measure

For the same redistribution rule an uncoordinated union always consumes more risky energy due to the moral hazard effect. Does this imply that the absence of coordination leads to an overconsumption of risky energy? Or, to put it differently, is more risky energy a good measure of social welfare? It turns out that this is not necessarily the case. Assume that the asymmetry between the countries is sufficiently high (in particular the other country is more exposed to risks than the leading country). The leading country, being the decision maker in an uncoordinated union, chooses the mutual insurance rule to be below the one in the coordinated union to avoid high moral hazard costs. This, in turn, decreases not only the risky energy consumption of the other country, but also the risky consumption of the leading country. So it might be the case that the risky energy consumption in an UU is smaller than in a CU. However, the aggregate welfare in UU is lower than in CU as the countries end up consuming too much of expensive safe energy and having too low level of mutual insurance. Therefore, risky energy consumption may not always be a relevant measure to predict the welfare outcomes of different constellations or to discuss the security of energy supply, especially when not controlling for the union form. It is important to use other proxies for an adequate welfare analysis.

4.3.4 Union participation

As we discussed above, in the absence of side payments some union constellations may make one member worse off than in an autarky. Obviously, the question is what would make this member enter the union.

Choice of the redistribution rule. In an uncoordinated union the leading country may always ensure the participation of the other country by choosing a redistribution rule that provides a slightly higher level of welfare than in an autarky. This weakens the leading country's decision-making power over the distribution rule but it is still beneficial to the leading country due to the possibility of mutual insurance. The same arrangement can be used in a coordinated union if the side payments are non-feasible or too costly.

Other motives. The countries may choose to stay in the union even if they lose from being part of the mutual insurance agreement if there are other benefits from joining the union, or other costs from staying outside it. There could be many kinds of benefits or losses. For example, the formation of a union may cause its members to improve their collaboration within the union, lowering the transaction costs on trade and related issues. A union may also link several issues on the agenda, such as common policies on different types of energy. In this case, losses along one dimension can be compensated by the gains along the other dimensions. At the same time, a union may impose costs on outsiders, for example by excluding them from a common infrastructure. This may provide the outside countries with an incentive to join the union in the absence of direct benefits from mutual insurance.

In all these cases the fact that some countries join the union even without an obvious gain in some of the issues on the agenda implies a redistribution of welfare within the union towards its more powerful members. To limit their power and to ensure a fair balance within the union one may unlink the agenda issues. In this case the countries that previously lost out would be able to agree to the common policy only on the issues they found beneficial. This would improve their bargaining position and put a restrain on the leading country(ies). To some extent this approach is currently followed by the European Union as it sets separate storage requirements for gas and oil. However, this may be not the most efficient outcome.

The way to improve efficiency would be to share the agenda setting power, in other words, to let different union members be proposers on different issues. In this case the integration would put a limit on the selfish behaviour of an agenda setter on each separate energy issue and allow for mutually beneficial trade-offs. Indeed, a non-cooperative choice in one area can always be punished by a response in the other areas covered by the union. Therefore, one could expect an integrated union to outperform the "collection" of unions on each separate energy type.

5 THE MODEL

We now proceed to modelling the choices of two countries consuming energy from safe and risky sources. We assume that the countries can either operate in an autarky or choose to form a union. In the latter case they are subject to the common energy policy focusing on solidarity/mutual insurance between these states. More precisely, the policy instrument we consider is the agreement to cover a share of losses when one of the members but not the other faces a negative energy supply shock. We provide an analysis, comparative statics and compare the welfare outcomes of three constellations:

- countries operating in autarky;

- countries forming an uncoordinated union (UU), the members of which "insure" each other against potential supplier default risks. Each country makes its energy consumption decision ignoring the effects it may have on the other country;

- and countries forming a coordinated union (CU). Here the members still "insure" each other, but all the policies are targeted to maximizing the joint welfare of the union.

Consider two countries $i = 1, 2$ that consume a single type of energy. Each country can write contracts for the delivery of energy with two types of producers, a "safe" one and a "risky" one. Country i's amount of energy contracted with the "safe" ("risky") producer is denoted by s_i (r_i) $i = 1, 2$, respectively. The energy from these two sources is perfectly substitutable in consumption. The difference between them is that the producer of the "safe" energy delivers exactly the contracted amount in all states of nature.[14] The "risky" energy producer faces exogenous probability of default. In other words, in some states of nature this producer will fail to supply the contracted amount to the consumers even though the payment has been made.

States of the nature. Let the respective set of the states of nature be denoted by $\Omega = \{(k, l)\}, k, l \in \{n, d\}$ where each state corresponds to the default risks faced by the two country members. First index k refers to country 1, second index l refers to country 2, "n" stands for "no default" and "d" stands for "default". For example,

$$\begin{aligned} (n, n) &= \{\text{country 1 does not face a default} \\ &\quad\ \text{country 2 does not face a default}\}, \\ (d, n) &= \{\text{country 1 faces a default,} \\ &\quad\ \text{country 2 does not face a default}\}, \text{ etc.} \end{aligned}$$

In what follows we refer to state (n, n) as the *safe state* and to state (d, d) as the state of *double default*. Also, for each country i, the state when i, but not j faces a default is called the state of *local default***,** and the state when j but not i faces a default is called the state of *foreign default*. For example, for country 1 the state of local default is state (d, n) and the state of foreign default is state (n, d).

[14] Alternatively, one can interpret the "safe" energy as the energy storage within the country, and the cost of the "safe" energy as the cost of building and serving that storage. However this interpretation would be more appropriate in a dynamic extention of our static setting.

The probability of each state taking place is given by a_{kl}:

		Country 2	
		no default	default
Country 1	no default	a_{nn}	a_{nd}
	default	a_{dn}	a_{dd}

To make our problem more realistic we introduce an additional assumption.

Assumption 1. *Each country faces a default in less than 50% of the cases.*

This assumption implies that the probability of neither of the countries facing a default a_{nn} is positive.[15] To strengthen our argument we further assume that the default probabilities cannot get infinitely close to 1/2, i.e., that there exists some positive lower bound of the joint no-default probability $a_{nn} \geq \delta > 0$.

Prices. We assume that the energy prices are exogenously given and normalize the price of risky energy to 1. We also assume that the countries face the same risky energy price (as it comes from the same producer) but may differ in the ease (and price) of access to the safe energy - some of them produce it at home while others have to import from the ("safe") outside sources, such as other EU members etc. Therefore the prices of the safe energy in the two countries are denoted by p_{s_i}, $i = 1, 2$. Clearly the equilibrium price of "risky" energy $p_r = 1$ should be below the price of the "safe" energy p_{s_i} for each country, otherwise no risky energy would ever be consumed

$$p_{s_i} > 1.$$

Therefore, a contract with the producer of "safe" energy S provides country i with an insurance against default. In other words, in choosing how much "safe" energy to consume, country i weights the cost of having an extra unit of "safe" energy in the non-default state (when the safe energy is more expensive than the risky one) against the benefit of holding it in a default state, (when the safe energy is the only option available).

[15]See appendix for the derivation.

Utility function. Each country maximizes its energy consumption in a safe state, while deviation from this level is costly. Namely, we consider the following payoff function

$$U_i = e_i^{nn} - \sum_{k,l \in \{n,d\}} a_{kl} C(e_i^{kl} - e_i^{nn}),$$

where e_i^{kl} is the aggregate energy consumption in the respective state of nature, a_{kl} is the probability of this state of nature and $C(.)$ is the cost of deviating from the energy consumption level in a safe state, concave and increasing function. To simplify our argument we choose

$$C(x) = \frac{x^2}{2}.$$

The respective energy budget is given by $B_i, i = 1, 2$.

Intuitively, this utility function would correspond to the case of a country choosing an optimal level of energy to satisfy its daily needs. Energy supply falling short of this level of consumption results in the underprovision of energy to some of the country's customers, which in turn requires a costly adjustment. This choice of the utility function is in line with the literature on the economic impact of an energy supply failure[16]. This literature focuses on the negative externalities created by an energy supply disruption and argues that supply failures entail adjustment costs.[17]

Policy instrument. We concentrate on a particular aspect of a common energy policy - mutual insurance within the union. The members of the union insure each other against default risks by redistributing energy in the states of nature when only one of the members faces the default - states (n, d) and (d, n). Clearly, this mutual insurance can only work if the default risks towards member countries are not perfectly correlated, i.e., when $a_{nd} + a_{dn} > 0$. In what follows we consider a special type of mutual insurance: we assume that the countries agree on a percentage λ of the default losses to be covered

[16]See CIEP report, 2004, pp.77-78 for a brief review.

[17]E.g., "the main short-term issues at stake in adjustment involve the decline in productivity and sticky wages, the premature obsoleteness of energy intensive capital goods and rigidities in factor prices and allocation." CIEP report (2004, p.78)

by the unaffected member.[18] We also assume that the mutual insurance outcomes are fully contractible and not renegotiable. In other words, the participating countries sign an agreement about the extent of mutual insurance and stick to that rule.

Timing. There are at most two stages in the game:

Stage 1. Countries 1 and 2 decide on rule λ that governs redistribution in case of asymmetric risks. In other words, if country i but not country j faces a default, country j transfers λr_i units of energy to country i. No action takes place in an autarky.

Stage 2. Countries 1 and 2 simultaneously choose their consumption of risky and safe energy, r_i and s_i, given their budget B_i, $i = 1, 2$. Then uncertainty is realized and transfers are made if needed. No redistribution occurs in the case of no default in both countries, or double default. No redistribution takes place in an autarky.

The way the first stage decision is taken depends on a particular union constellation. We discuss this in more detail in the respective sections.

In what follows we present our results and support them by intuition. All proofs and derivations are relegated to the Appendix.

5.1 Autarky

In an autarky each country operates on its own and there is no common energy policy, i.e., no mutual insurance is employed. We start by considering the energy consumption decision of a single country i. Here country i contracts on the amounts of safe energy s_i and risky energy r_i and then the uncertainty is realized. Country i's decision does not depend on whether or not country j faces a default. The consumption of energy in each state of nature is summarized in Table 8.

Therefore country 1 chooses its risky and safe energy consumption

[18] In the model we think of the mutual insuranse in terms of a physical transfer of energy. However, we believe that the same qualitative results would hold in case mutual insurance is implemented through monetary compensations.

Table 8. Different State Outcomes in Autarky

State of nature	Prob	Total energy consumption		Deviation from the safe state cons. e_i^{nn}	
		country 1, e_1^{kl}	country 2, e_2^{kl}	country 1	country 2
(n,n)	a_{nn}	$e_1^{nn} = r_1 + s_1$	$e_2^{nn} = r_2 + s_2$	0	0
(n,d)	a_{nd}	$e_1^{nd} = r_1 + s_1$	$e_2^{nd} = s_2$	0	$-r_2$
(d,n)	a_{dn}	$e_1^{dn} = s_1$	$e_2^{dn} = r_2 + s_2$	$-r_1$	0
(d,d)	a_{dd}	$e_1^{dd} = s_1$	$e_2^{dd} = s_2$	$-r_1$	$-r_2$

by maximizing

$$\max_{r_1} s_1 + r_1 - 1/2\left[(a_{dn} + a_{dd})(r_1)^2\right]$$
$$s.to \;\; p_{s_1} s_1 + r_1 \leq B_1$$

Taking the first order conditions and solving them yields the optimal consumption of risky energy for country 1:

$$r_1^A = \frac{1 - 1/p_{s_1}}{a_{dn} + a_{dd}}. \tag{1}$$

where the subscript A stands for "autarky". Similarly, country 2 consumes r_2^A units of risky energy,

$$r_2^A = \frac{1 - 1/p_{s_2}}{a_{nd} + a_{dd}}. \tag{2}$$

Comparative statics.

We see that the risky consumption increases with the price of the (substitutable) safe energy and decreases with the risk of default. Denote the welfare of country i resulting from solving this problem by $W_{A,i}^*$. Then the following result holds.

Result 1 *The welfare of country i decreases with the price of its own safe energy*

$$\frac{dW_{A,i}^*}{dp_{s_i}} < 0, \quad i = 1, 2$$

as well as with the aggregate risk of default

$$\frac{dW^*_{A,1}}{d\left(a_{dn}+a_{dd}\right)} < 0,$$
$$\frac{dW^*_{A,2}}{d\left(a_{nd}+a_{dd}\right)} < 0.$$

Intuitively, a higher price of the safe energy implies that country i has to cut its aggregate energy consumption, which, in turn, leads to a welfare loss. A higher risk of default leads to a shift towards safe energy in country 1's energy consumption bundle. Since safe energy is more expensive, this shift lowers country 1's welfare.

5.2 Uncoordinated union

Now the two countries 1 and 2 form a union with a common energy policy. This implies that they can rely on the mutual insurance provided within the union. We analyze the benefits of joining the union and possible costs that the mutual insurance may involve by providing the member countries with the wrong incentives.

Mutual insurance implies that there could be four potential outcomes at stage 2, which are summarized in Table 9. In other words, mutual insurance lowers the default loss of the affected member at the expense of the other party. The utility of each country member in the union is given by

$$\begin{aligned} & U_1(s_1, r_1, r_2, \lambda) \\ & = s_1 + r_1 - \frac{a_{nd}\left(\lambda r_2\right)^2 + a_{dn}\left((1-\lambda) r_1\right)^2 + a_{dd}(r_1)^2}{2} \end{aligned} \tag{3}$$

and

$$\begin{aligned} & U_2(s_2, r_2, r_1, \lambda) \\ & = s_2 + r_2 - \frac{a_{nd}\left((1-\lambda) r_2\right)^2 + a_{dn}\left(\lambda r_1\right)^2 + a_{dd}(r_2)^2}{2}. \end{aligned} \tag{4}$$

Consider a situation where countries 1 and 2 make uncoordinated decisions at the second stage of the game. Namely, they use the mutual insurance opportunity provided by the union but they take their decisions about s_i and r_i, $i = 1, 2$, separately, not taking the effect on the welfare of the other union member into account.

Table 9. Different State Outcomes under Mutual Insurance

State of nature	Prob	Total energy consumption by country 1, e_1^{kl}	Total energy consumption by country 2, e_2^{kl}	Deviation from the safe state energy consumption e_i^{nn}: country 1	Deviation from the safe state energy consumption e_i^{nn}: country 2
(n,n)	a_{nn}	$e_1^{nn} = r_1 + s_1$	$e_2^{nn} = r_2 + s_2$	0	0
(n,d)	a_{nd}	$e_1^{nd} = r_1 + s_1 - \lambda r_2$	$e_2^{nd} = s_2 + \lambda r_2$	$-\lambda r_2$	$-(1-\lambda) r_2$
(d,n)	a_{dn}	$e_1^{dn} = s_1 + \lambda r_1$	$e_2^{dn} = r_2 + s_2 - \lambda r_1$	$-(1-\lambda) r_1$	$-\lambda r_1$
(d,d)	a_{dd}	$e_1^{dd} = s_1$	$e_2^{dd} = s_2$	$-r_1$	$-r_2$

We also assume that the mutual insurance rule, i.e., the proportion of loss coverage λ is chosen by country 1. We refer to country 1 as the *leading country*. There are several reasons why one of the member countries may have more influence over the common energy policy. The country may be overrepresented in a joint legislative body, e.g. because it is more populous, or it may be an agenda setter in this body and thus have leverage over the decisions. Alternatively, some union members may be more influential than the others for certain institutional or historical reasons. Indeed, this seems to be the case within the European Council, as documented by Tallberg (2007) who argues that "the states most advantaged in structural terms – France, Germany, and the UK – also tend to exert the greatest influence in European Council negotiations" despite formally equal treatment of all EU members.[19] Example 1 provides some evidence for the uneven allocation of energy policy bargaining power in the EU. Finally, this may be an outcome of the unanimity decision rule, widely used in the decision-making process in the European Union. It is known in the literature that the unanimity rule may bias policy decisions towards the preferences of one of the members. In particular, Berglof et al. (2007, 2008) argue that in a heterogeneous union the unanimity rule may benefit weak members, holding back the entire union and hampering reforms.[20] Thus, our assumption corresponds to the case of a strong imbalance as regards the allocation of policy influence, with all of the bargaining power concentrated in hands of only one union member. Later on in the report we address the implications of relaxing this assumption.

Example 1 (Energy policy influence disparity) *Since 2005 Germany has consistently pushed for the construction of the "Nord-Stream" pipeline, a German-Russian gas link, arguing that "it is the project of the whole Europe that is needed for diversification of Europe's energy supply channels," (Frank-Walter Steinmeier, Minister of For-*

[19] One can interpret the two countries in our model as a simplification of the situation with two groups of countries, one being more influential than the other.

[20] Our further discussion of the case of asymmetric countries, with country 1 more affected by risks than country 2, provides an example of a weak member gaining at the expense of the other party.

eign Affairs of Germany, 12 July 2007, Baltic Business News). The project progresses despite strong opposition from Poland which loses its negotiating power and economic advantage from the energy transit. So, in some sense, Poland has been put into a take-it-or-leave-it position, facing a choice of either joining the European common energy programme (and thus agreeing to a Germany-imposed policy suggestion) or just staying completely outside it. At the same time, an early 2006 energy solidarity initiative proposed by Poland was rejected by Germany and France (Geden et al., 2006). These observations suggest that different EU members may indeed exert a very uneven level of influence over the common energy policy.

The game is solved by backward induction, starting with the decisions of the second stage and then rolling backwards to the first stage.

Stage 2. At the second stage each member country determines its consumption of risky and safe energy taking λ as given. Country 1 maximizes

$$\max_{r_1} U_1(s_1, r_1, r_{2,}\lambda)$$
$$s.t.\ p_{s_1}s_1 + r_1 \leq B_1,$$

where $U_1(s_1, r_1, r_{2,}\lambda)$ is given by equality (3). The respective FOC yields the best-preferred choice of risky energy consumption of country 1 in an uncoordinated union as a function of redistribution rule λ and the exogenous parameters of model

$$r_1^{UU}(\lambda) = \frac{1 - 1/p_{s_1}}{a_{dn}(1-\lambda)^2 + a_{dd}}. \tag{5}$$

Similarly, country 2's choice of risky energy for the given redistribution rule λ is

$$r_2^{UU}(\lambda) = \frac{1 - 1/p_{s_2}}{a_{nd}(1-\lambda)^2 + a_{dd}}. \tag{6}$$

Partial comparative statics for risky energy consumption.

Before proceeding backwards to the first stage, we analyze the partial comparative statics of this choice with respect to the exogenously given risk probabilities, prices and the first-period decision variable λ.

As concerns one more exogenous parameter of the model, the energy budget B, the model is specified in such a way that B only affects country's welfare through the safe energy consumption, having no impact on this risky energy consumption and the mutual insurance rule λ. Other things equal, countries with higher energy budget enjoy higher welfare. This simplification is done to keep the model tractable and can be relaxed. That may allow for the discussion of the effect of country's size on its behavior within the union. However we believe that it will not change the qualitative predictions concerning the moral hazard problem.

Mutual insurance and risky energy. The more mutual insurance there is, the higher the consumption of risky energy.

$$\frac{\partial r_i^{UU}}{\partial \lambda} > 0.$$

This is a result of a free-riding incentive resulting from the mutual insurance provided in the union. We later refer to it as to a moral hazard effect.

Price and risky energy. The cheaper the (own) safe energy is for the country, the lower the consumption of risky energy.

$$\frac{\partial r_i^{UU}}{\partial p_{s_i}} > 0.$$

This is a fairly intuitive result: the risky energy is not being supplied in the default state of nature, so it is only consumed in this economy because it is cheaper than the safe one. As the price of the risky energy becomes relatively more expensive, it is substituted with the safe energy in the consumption bundle.

Default probability and risky energy. Unlike in the case of the autarky, the effect of an arbitrary increase in the probability of default $a_{dn} + a_{dd}$ that country 1 faces on its consumption of risky energy is now ambiguous. Indeed, this probability can be decomposed into two parts: probability of "double default" a_{dd} and probability a_{dn} of the local default state (d,n). An increase in each of these two probabilities holding the other one fixed lowers the consumption of risky energy

$$\begin{aligned}\frac{\partial r_1^{UU}}{\partial a_{dn}} &< 0,\\ \frac{\partial r_1^{UU}}{\partial a_{dd}} &< 0.\end{aligned}$$

The intuition here is similar to the one in the autarky case: in both these states country 1 pays (at least part of) the costs of consuming risky energy. The higher the respective probability, the higher the associated cost and thus the lower the incentive to purchase risky energy. So if an increase in the probability of default is a result of a (weak) increase in both components, it lowers the risky energy consumption of country 1.

However, if an increase in the probability of default $a_{dn}+a_{dd}$ is, say, caused by an increase in the probability of double default a_{dd} accompanied by less than a proportional decrease in a_{dn}, the overall effect of this increase is now ambiguous. Indeed, a higher a_{dd} provides a stronger incentive to cut the risky consumption, while a lower a_{dn} provides an opposite incentive so that the net effect is unclear.

Also, the effect of a change in the risk of double default a_{dd} on the risky energy consumption is stronger than the effect of the same size change in unilateral default a_{dn}. For example, assume that the total probability of default in country 1 stays the same, so that the increase in the probability of being bailed out is exactly offset by the decrease in the probability of double default.

$$\begin{aligned}\widetilde{a}_{dn}+\widetilde{a}_{dd} &= \widetilde{\widetilde{a}}_{dn}+\widetilde{\widetilde{a}}_{dd},\\ \widetilde{a}_{dn} &= \widetilde{\widetilde{a}}_{dn}+\delta,\\ \widetilde{a}_{dd} &= \widetilde{\widetilde{a}}_{dd}-\delta.\end{aligned}$$

In this case country 1 consumes more risky energy.

$$r_1^{UU}\left(\lambda,\widetilde{a}_{dn},\widetilde{a}_{dd}\right) > r_1^{UU}\left(\lambda,\widetilde{\widetilde{a}}_{dn},\widetilde{\widetilde{a}}_{dd}\right)$$

This is due to the fact that the mutual insurance makes country 1 face only part of the costs of the risky energy consumption when it is bailed out. As a result, country 1 is less sensitive to a change in the respective probability.

Also, at this stage the choice of country 1 is not influenced by the foreign default probability, i.e., the probability of the state in which it has to bail out the second country a_{nd}.[21] This is due to the fact that country 1 cannot affect the decisions of country 2 on risky energy consumption.

Obviously, the same set of arguments and results works for country 2.

Stage 1. Now we proceed to stage 1 - the choice of λ. If country 1 is the one deciding on the degree of compensation λ, it sets λ by maximizing its utility while taking into account the reaction of country 2 to the choice of λ in stage 2. Therefore country 1 solves:

$$\begin{aligned}
&\max_{\lambda} s_1 + r_1 - \frac{1}{2}\left[a_{nd}\left(\lambda r_2\right)^2 + a_{dn}\left((1-\lambda)r_1\right)^2 + a_{dd}(r_1)^2\right] \\
&s.to \;\; p_{s_1}s_1 + r_1 \leq B \\
&\quad r_1 = \frac{1 - 1/p_{s_1}}{a_{dn}(1-\lambda)^2 + a_{dd}} \\
&\quad r_2 = \frac{1 - 1/p_{s_2}}{a_{nd}(1-\lambda)^2 + a_{dd}}
\end{aligned}$$

Taking the first order conditions with respect to λ, using the envelope theorem for the optimally chosen r_1 and substituting the expression for $\partial r_2/\partial\lambda$ from (6) we arrive at an implicit equation that determines the choice of redistribution by country 1 in an uncoordinated union λ_1^{UU}

$$-\lambda_1^{UU}\left(a_{nd}r_2^2 + a_{dn}r_1^2 + \frac{2\lambda_1^{UU}(1-\lambda_1^{UU})a_{nd}^2 r_2^3}{(1-1/p_{s_2})}\right) + a_{dn}r_1^2 = 0, \tag{7}$$

where r_i are given by equations (5) and (6). The best-preferred λ for the second country can be found in the same way.

Lemma 1 *There exists a* $\lambda^{UU} \in (0,1)$ *that maximizes country 1's utility.*

[21] As far as an interior solution is concerned.

Lemma 1 suggests that such a λ always determines an interior solution. To put it differently, country 1 will always prefer some mutual redistribution to remaining in an autarky and will never choose to cover all of country 2's losses. If there are more than one $\lambda \in (0, 1)$ maximizing country 1's utility, country 1 may benevolently pick the one preferred by country 2. However in what follows (especially in the comparative statics discussion) we concentrate on the case when such a λ^{UU} is unique.

Assumption 2. *The set of the exogenous parameters of the model ensures that each country has a unique best-preferred redistribution rule.*

This assumption is not very restrictive. In particular, all the cases where countries are not very asymmetric in terms of default risks, including all of our numerical simulation examples fall into this category. More technical discussion on this assumption can be found in the Appendix.

Example 2 (Symmetric case, Uncoordinated Union) *Consider a union of two completely identical countries facing identical risks ($a_{nd} = a_{dn}$, $p_{s_i} = p_s$ and $r_1 = r_2 = r$). The equation (7) then becomes*

$$\lambda^{UU} = \frac{1}{2} - \frac{a_{nd}\left(\lambda^{UU}\right)^2(1-\lambda^{UU})}{a_{nd}(1-\lambda^{UU})^2 + a_{dd}}. \tag{8}$$

The equation determining the best-preferred λ of country 2 *will be exactly identical. Note that the equation (8) implies that in the symmetric case the insurance coverage in an uncoordinated union will never exceed 1/2, because*

$$\frac{a_{nd}\lambda^2(1-\lambda)}{a_{nd}(1-\lambda)^2 + a_{dd}} > 0,$$

and will always be above 0 *(see Appendix). Therefore, a symmetric case always yields an interior solution for λ.*

Comparative statics for redistribution rule λ.

This subsection addresses the reaction of country 1's preferred redistribution rule to the change in the exogenous parameters of our model.

Redistribution rule and the price of the safe energy. Consider first the effect of the price of the own safe energy. The more expensive country 1's safe energy is, the more risky energy country 1 consumes and the greater proportion of its energy bundle is affected by risks. Other things being equal, this increases country 1's willingness to raise the coverage in the mutual insurance agreement. Now turn to the effect of the price of the risky energy in the second country. Similarly to above, the higher this price is, the more risky energy the second country consumes. As a result, the cost of bailing out the second country increases for country 1, which is thus willing to reduce the mutual insurance compensation. We summarize this intuition in the following statement:

Result 2 *Other things being equal, an uncoordinated union with more expensive safe energy in country 1 is associated with higher mutual insurance λ. In contrast, a union with a higher price of safe energy in country 2 is characterized by a lower redistribution rule.*

$$\frac{d\lambda^{UU}}{dp_{s_1}} > 0; \quad \frac{d\lambda^{UU}}{dp_{s_2}} < 0.$$

Redistribution rule and default probabilities. There are 4 possible states of nature (and 4 corresponding probabilities). As the sum of all 4 probabilities is 1, the effect of a change in the probability of one of the states can be found as a linear combination of the other 3 effects. We concentrate on the change in the probabilities of the states when at least one country faces a default. Namely, we consider changes in probability a_{dn} of the state when only country 1 faces a default, probability a_{nd} of the state when only country 2 faces a default and probability a_{dd} of the state when both countries face a default. To isolate the respective effects in the analysis below we assume that an increase in probability a_{dn} (or a_{nd}, or a_{dd}) is accompanied by the same magnitude decrease in the probability of safe state a_{nn}.[22] A more precise interpretation of this assumption will be discussed in each of the cases considered below.

Start with the effect of the probability of the state when only country 1 faces a default a_{dn}. In this case an increase in a_{dn} accompanied

[22] So that the sum of the 4 probabilities is still equal to 1.

by a decrease in a_{nn} corresponds to a situation where the aggregate probability of default (and aggregate probability of no default) for country 2 does not change.

		Country 2	
		no default	default
Country 1	no default	$a_{nn} - \delta$	a_{nd}
	default	$a_{dn} + \delta$	a_{dd}

Moreover, none of the probabilities of the states when country 2 faces a default a_{nd}, a_{dd} is altered. Therefore, country 2's choice of risky energy r_2^{UU} given by formula (6) can only be affected through a change in redistribution rule λ.

An increase in a_{dn} has two effects. First, the state in which country 1 is bailed out is realized more frequently, which induces country 1 to choose a higher λ. Second, other things being equal, a higher a_{dn} lowers country 1's consumption of risky energy. As a result, country 1 does not value the compensation of share λ of risky consumption as much as before. In other words, a higher a_{dn} reduces country 1's benefits from mutual insurance and thus, an optimal λ should fall. When a_{dn} is small relative to a_{dd}, the first effect dominates as the risky energy consumption of country 1 is not very sensitive to the change in a_{dn} (see equation (5)). As a_{dn} increases, the relative size of the two effects changes. For high values of a_{dn} the second effect may dominate.

Now let us turn to the increase in the probability of the foreign default for country 1, i.e., the state when only country 2 faces a default a_{nd} accompanied by the same sized decrease in a_{nn}. Similarly to above, it corresponds to the situation when the total probabilities of default for the first country are unaffected by this change, and thus the effect on country 1's choice of risky consumption only comes through λ.

Again, an increase in a_{nd} has two effects. First, it increases the frequency of the states in which country 1 has to compensate country 2, which induces country 1 to choose a lower λ. Second, other things being equal, an increase in a_{nd} presses down country 2's consumption of risky energy. This implies lower costs for country 1 (partially) compensating country 2's default loss, while country 1's gains from the mutual insurance stay the same. Thus an optimal λ should increase. When a_{nd} is small relative to a_{dd} the first effect dominates, because the risky energy consumption of the second country r_2 is not very sensitive to a change in a_{nd} (see (6)). Therefore λ falls as a_{nd} increases. For high values of a_{nd} the second effect dominates and a further increase in a_{nd} may cause an increase in λ.

Finally, consider the effect of the increase in the probability of double default a_{dd}. This change does not have a direct impact on the mutual insurance incentives, but it may influence it indirectly through the risky energy choices of the member countries. A higher a_{dd} decreases the risky energy consumption of the second country which would induce a higher λ. At the same time it decreases the risky energy consumption of the first country which would lower λ. The final outcome depends on the relative size of the two effects.

The following statement summarizes the findings concerning the impact of default probabilities on the redistribution rule.

Result 3 *The probability of local default for country 1 a_{dn}, the probability of foreign default for country 1 a_{nd}, and the probability of double default a_{dd} have an ambiguous effect on the redistribution rule λ.*

Full comparative statics for risky energy consumption.

In this subsection we study the total impact of the exogenous parameters (such as prices and default probabilities) on the countries' choice of risky energy consumption. To analyze it, one needs to account for two effects: First, there is a direct effect that has been addressed in the discussion on the partial comparative statics. Second, there is an effect coming through the redistribution rule λ (chosen by the leading country - country 1).

A higher price of the own safe energy raises country 1's risky energy consumption as both effects work in the same direction. More expensive safe energy shifts country 1's consumption bundle towards the risky energy which provides a stronger incentive to rely on mutual insurance. The latter, in turn, increases the risky energy consumption even further. As for the second country, the effect of an increase in its own safe energy price is not clear, as the direct effect of p_{s_2} on r_2 is positive, but the indirect effect that comes through λ is negative as shown in Result 2. Indeed, higher risky consumption in country 2 makes country 1 less willing to get involved in the mutual insurance agreement, which lowers redistribution rule λ.

The safe energy price in country i does not have a direct impact of on the risky energy consumption in country j. Therefore, all the effect comes through the change in redistribution rule λ. Country 2's safe energy price p_{s_2} decreases the redistribution rule and thus lowers the risky consumption in country 1. In turn, country 1's safe energy price p_{s_1} raises λ which has a positive impact on the risky energy consumption in country 2 r_2. These results are summarized in the following table

$$\frac{dr_1^{UU}}{dp_{s_1}} > 0; \qquad \frac{dr_2^{UU}}{dp_{s_1}} > 0;$$
$$\frac{dr_1^{UU}}{dp_{s_2}} < 0; \qquad \frac{dr_2^{UU}}{dp_{s_2}} >< 0.$$

Since the probabilities of different states have an ambiguous effect on redistribution rule λ, the risky energy consumption in both countries may also change in either direction with respect to changes in a_{nd}, a_{dn} and a_{dd}.

Result 4 *Consider two uncoordinated unions. Other things being equal,*

a. *Both members of a union with a higher safe energy price in country 1 consume more risky energy. If the union faces more expensive safe energy in the second country, country 1 cuts its risky consumption, while the effect on the second country is unclear.*

b. *The default probabilities have an ambiguous effect on risky energy consumption in both countries.*

Comparative statics for welfare.

Country 1. We start by discussing the results for country 1. Being a *leading* union member, country 1 determines redistribution rule λ. Thus both λ and risky energy consumption r_1 are chosen to maximize country 1's utility. As a result, a change in λ and r_1 caused by the change in the exogenous parameters, such as safe energy prices or default probabilities, will not affect the welfare of country 1.[23] The overall impact of an exogenous parameter on the welfare of country 1 will be composed of direct effect $\partial W_1/\partial a_{kl}$ (or $\partial W_1/\partial p_{s_i}$) and the indirect effect through the change in country 2's risky energy consumption r_2.

Country 1. Effect of prices. A higher price of own safe energy lowers country 1's welfare since for a given budget it implies a lower (total) energy bundle

$$\frac{dW_1}{dp_{s_1}} < 0.$$

A higher price of country 2's safe energy increases country 2's risky energy consumption. As country 1 has to (partially) compensate country 2 for the loss of this energy in the state when only country 2 faces a default, it lowers country1's welfare

$$\frac{dW_1}{dp_{s_2}} < 0.$$

Country 1. Effect of default probabilities. A higher probability of local default a_{dn} implies that country 1 faces an undersupply of energy more often which decreases its welfare

$$\frac{dW_1}{da_{dn}} = \frac{\partial W_1}{\partial a_{dn}} < 0.$$

A higher probability of foreign default a_{nd} has an ambiguous effect on the welfare of country 1

$$\frac{dW_1}{da_{nd}} = \frac{\partial W_1}{\partial a_{nd}} + \frac{dW_1}{dr_2}\frac{\partial r_2}{\partial a_{nd}} <> 0.$$

[23]Mathematically, this outcome follows from the envelope theorem.

Indeed, it increases the costs of country 1 due to a higher probability of compensating country 2. At the same time, it lowers the risky consumption of country 2 which decreases the value of compensation.

Finally, a higher probability of double default a_{dd} has an ambiguous effect too: it lowers the risky consumption of country 2, which increases country 1's welfare. At the same time it increases the probability of default for country 1 which is costly for country 1.

$$\frac{dW_1}{da_{dd}} = \frac{\partial W_1}{\partial a_{dd}} + \frac{dW_1}{dr_2}\frac{\partial r_2}{\partial a_{dd}} <> 0.$$

Note that it also lowers the risky energy consumption of country 1 but this does not have any effect on the welfare due to the efficient choice of r_1 (and the envelope theorem).

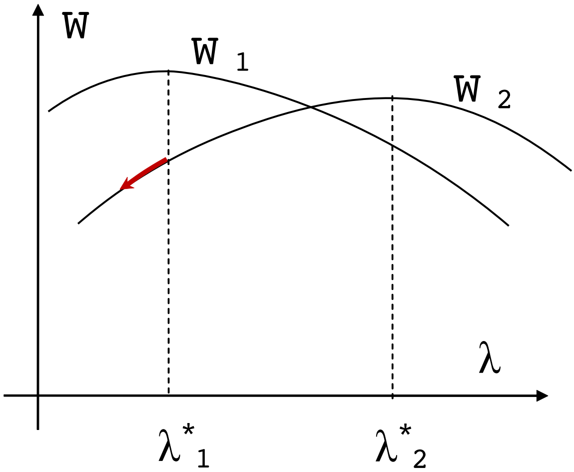
Country 2. Now we turn to the analysis of the welfare of the second country. Consider an effect of a change in an exogenous parameter. The envelope theorem can only ensure no effect through the choice of r_2 since r_2 is chosen to maximize country 2's welfare. However, mutual insurance rule λ is no longer optimal from country 2's point of view. So the welfare will be affected both through mutual insurance rule λ and the risky energy consumption of the other country r_1. Namely, the overall effect of a change in the exogenous parameter (such as a price or a probability of a respective state) on the welfare of country 2 will consist of a direct and an indirect effect. The latter reflects the change in r_1 and the change in redistribution rule λ. For example, for the own safe energy price p_{s_2},

$$\begin{aligned}\frac{dW_2}{dp_{s_2}} &= \frac{\partial W_2}{\partial p_{s_2}} + \frac{\partial W_2}{\partial \lambda}\frac{d\lambda}{dp_{s_2}} + \frac{\partial W_2}{\partial r_1}\frac{dr_1}{dp_{s_2}} \\ &= \frac{\partial W_2}{\partial p_{s_2}} + \frac{\partial W_2}{\partial \lambda}\frac{d\lambda}{dp_{s_2}}\end{aligned}$$

as $dr_1/dp_{s_2} = 0$.

Country 2. Effect of prices. The effect of own price on welfare will be determined by the characteristics of the second country. The direct effect of the increase in the own safe energy price is negative and redistribution rule λ decreases with the price of the safe energy

Figure 2. Welfare of Union Members as a Function of Redistribution Rule



in the second country.

$$\frac{\partial W_2}{\partial p_{s_2}} < 0,$$
$$\frac{d\lambda}{dp_{s_2}} < 0.$$

Assumption 5.2 suggests that there is a single best preferred redistribution rule for each country. If country 2 prefers more mutual insurance than country 1 ($\lambda_2^* > \lambda_1^*$), its welfare decreases with a decrease in λ around the best preferred choice of the leading country λ_1^* (see Figure 2 for illustration).

As a result, the overall effect of an increase in the price of the safe energy in country 2 on country 2's welfare will be negative

$$\frac{dW_2}{dp_{s2}} = \frac{\partial W_1}{\partial p_{s_2}} + \frac{\partial W_1}{\partial \lambda}\frac{d\lambda}{dp_{s2}} < 0.$$

In other words, the welfare of country 2 decreases with the price of its own safe energy as it drives country 2 away from its preferred redistribution rule. If instead country 2 prefers less redistribution than country 1, the overall effect of p_{s_2} on country 2's welfare is ambiguous. On the one hand, country 2 suffers from facing a more expensive energy consumption bundle (direct effect). On the other hand, its welfare increases from a lower λ, i.e., it gains from moving closer to its best preferred redistribution rule λ_2^*.

Now let us look at the effect of the increase in country 1's safe energy price p_{s_1}. A higher price of country 1's safe energy increases risky energy consumption in country 1. This lowers country 2's welfare as it has to compensate country 1 when there is a unilateral default. At the same time, a higher p_{s_1} implies a higher λ. The effect of this increase in λ on country 2's welfare depends on the mutual insurance preferences of country 2. If country 2 prefers less redistribution than country 1, its welfare will decrease with p_{s_1}. Indeed, a higher p_{s_1} implies higher risky consumption in country 1 and, as a result, more redistribution, both of which are detrimental to country 2's welfare. If instead country 2 prefers more redistribution than country 1, the effect is ambiguous.

Country 2. Effect of default probabilities. A change in all 3 probabilities will generally have an ambiguous effect on the welfare of country 2 (as it has an ambiguous effect on redistribution rule λ).

The following statement summarizes the findings of this subsection.

Result 5 *Compare two uncoordinated unions. Other things being equal,*

a. *The welfare of the leading country - country 1 - is lower in a union with more expensive safe energy;*

b. *If country 2 prefers more mutual insurance than country 1, it is worse off in a union facing a higher price on country 2's safe energy. If country 2 is relatively less interested in redistribution, its welfare is lower in a union with more expensive country 1's safe energy. Otherwise the effect is ambiguous;*

c. *A higher probability of local default decreases country 1's welfare. All other default probability effects on both countries are unclear.*

5.3 Coordinated union

Now consider the case of a union where the behaviour of its members is perfectly coordinated. Mutual insurance implies that the outcomes in such a union are still summarized by Table 9 and the utility of union members is given by formulas (3) and (4) (similarly to the uncoordinated union). However, the incentives within the union are different now. Namely, there is a social planner that maximizes the joint welfare of the two countries $U_1 + U_2$

$$
\begin{aligned}
&U_1(s_1, r_1, r_2, \lambda) + U_2(s_2, r_2, r_1, \lambda) = \\
&\left\{ s_1 + r_1 - \frac{1}{2}\left[a_{nd}\,(\lambda r_2)^2 + a_{dn}\,((1-\lambda)r_1)^2 + a_{dd}(r_1)^2\right]\right. \\
&\left. + s_2 + r_2 - \frac{1}{2}\left[a_{nd}\,((1-\lambda)r_2)^2 + a_{dn}\,(\lambda r_1)^2 + a_{dd}(r_2)^2\right]\right\},
\end{aligned}
$$

and prescribes choices to both countries. Again, we solve the problem by backward induction.

Stage 2. At the second stage the social planner chooses the risky consumption of both countries by solving

$$
\begin{aligned}
&\max_{r_1, r_2} U_1(s_1, r_1, r_2, \lambda) + U_2(s_2, r_2, r_1, \lambda) \\
&s.t.\ p_{s_i} s_i + r_i \leq B_i, \quad i = 1, 2.
\end{aligned} \tag{9}
$$

Solving the FOC conditions for risky consumption r_1 and r_2 yields:

$$
r_1^{CU}(\lambda) = \frac{1 - 1/p_{s_1}}{a_{dn}\left[(1-\lambda)^2 + \lambda^2\right] + a_{dd}}, \tag{10}
$$

$$
r_2^{CU}(\lambda) = \frac{1 - 1/p_{s_2}}{a_{nd}\left[(1-\lambda)^2 + \lambda^2\right] + a_{dd}} \tag{11}
$$

The (partial) comparative statics effects with respect to p_{s_i}, the risk of default and the correlation between the shocks have the same signs as these effects in an uncoordinated union. In other words, the consumption of risky energy r_i^{CU} increases with the price of safe energy p_{s_i}. The effect of a higher overall default probability is ambiguous, and the effect of its two components is negative.

However, the effect of the mutual insurance is different from the case of an uncoordinated union. The social utility maximizer takes into account the negative externality imposed on country j by the risky energy consumption of country i. For small values of λ this externality cost is low and the union benefits from higher redistribution. However for sufficiently high values of λ ($> 1/2$) the cost becomes disproportionally high compared to the benefits of mutual insurance and the social planner reacts by decreasing the risky energy consumption.

Note also that for the same redistribution rule λ the consumption of risky energy in an uncoordinated union always exceeds the consumption of risky energy in a coordinated union due to the free-riding (=moral hazard) effect:

$$\begin{aligned} r_1^{UU}(\lambda) &= \frac{1 - 1/p_{s_1}}{a_{dn}\left[(1-\lambda)^2\right] + a_{dd}} \\ &> \frac{1 - 1/p_{s_1}}{a_{dn}\left[(1-\lambda)^2 + \lambda^2\right] + a_{dd}} = r_1^{CU}(\lambda) \end{aligned}$$

Stage 1. The social utility maximizer chooses how much insurance λ^{CU} to provide. Solving the FOC of maximization problem (9) with respect to λ yields

$$\lambda^{CU} = 1/2.$$

Note that this result does not depend on the degree of asymmetry between the countries, or, more generally on the default probabilities or safe energy prices. The intuition behind this result is as follows: the social planner minimizes the joint loss from the redistribution in each of the states when one but not the other country faces a default. For our utility specification the optimal redistribution rule implies that each party covers the cost of exactly half the default loss no matter what the asymmetry between the countries is. Moreover, the result is independent of the functional form of the adjustment cost function as long as it is concave.

The substitution of $\lambda^{CU} = 1/2$ into the equations (10) and (11) yields the risky consumption of the two union members in a coordinated union:

$$r_1^{CU} = \frac{1 - 1/p_{s_1}}{a_{dn}/2 + a_{dd}}$$
$$r_2^{CU} = \frac{1 - 1/p_{s_2}}{a_{nd}/2 + a_{dd}}$$

Example 3 (Symmetric case, Coordinated Union) *In a completely symmetric case the decision of the social planner concerning the choice of the risky energy consumption is given by*

$$r_1^{CU} = r_2^{CU} = r^{CU} \equiv \frac{1 - 1/p_s}{a_{dn}/2 + a_{dd}}.$$

Note that in the case of symmetric countries the redistribution rule $\lambda^{CU} = 1/2$ *corresponds to the full insurance policy between the two states with asymmetric shocks (d,n) and (n,d). That is, it equalizes the energy consumption between these two states for both countries:*

$$s_i + r_i - 1/2 r_j = s_i + 1/2 r_i,\ i = 1, 2.$$

Comparative statics for welfare.

In this subsection we analyze the effects of the exogenous parameters on the welfare of country 1. Clearly the effects on the welfare of country 2 will be symmetric. Note also that the envelope theorem cannot be applied to the analysis of the welfare response in each country as both the energy consumption and the redistribution rule are chosen to maximize the *joint* welfare of the union.

Effect of prices. The effect of the own safe energy price p_{s_1} on country 1's welfare is ambiguous in the case of a coordinated union. The reason for it is as follows. On the one hand, the direct effect is negative as before: a higher price of safe energy means a more expensive consumption bundle which decreases welfare. On the other hand, for a given redistribution rule $\lambda = 1/2$, country 1's best preferred risky energy consumption will exceed the one chosen by the social planner in a CU due to the free-riding incentive. Therefore a higher safe energy price increases risky consumption and brings country 1 closer to its "unilateral" optimum, which has a positive impact on welfare. If the probability of country 1 facing a local default a_{dn} is low, the free-riding incentive is weak and the "unilateral" choice of risky consumption of country 1 does not differ much from the socially optimal one. As a result the welfare effect of an increase in risky consumption is weak and the overall effect of the increase in p_{s_1} is negative due to the direct effect. If instead a_{dn} is high, country 1's best preferred risky consumption is much higher than in a CU. Therefore country 1 obtains a substantial marginal welfare gain from an extra unit of risky consumption. For sufficiently high a_{dn} the overall effect of the increase in p_{s_1} may become positive.

The welfare of country 1 decreases with the price of the safe energy in the second country p_{s_2}. The more expensive safe energy in country 2 is, the higher risky consumption in country 2. Country 1 has to (partially) compensate for the loss of this consumption in the state when country 2 faces a unilateral default, therefore its welfare decreases.

Effect of default probabilities. An increase in the local default probability a_{dn} has a negative effect on welfare. It imposes higher costs on country 1 through the direct (probability) effect. At the same time a_{dn} decreases the risky consumption which has an ambiguous effect on welfare. However the first effect always dominates.

The higher probability of bailing out the other country a_{nd} has an ambiguous effect. As before, the direct (probability) effect is negative, while the indirect effect through the fall in the risky consumption of country 2 is positive. If the chances of bailing out country 2 are sufficiently small (a_{nd} is low), the first effect dominates.

Finally, a higher probability of joint default a_{dd} has an ambiguous effect on country 1's welfare. It decreases the risky consumption of country 2, which benefits country 1. At the same time it has a direct negative (probability) effect on the welfare of country 1 and an indirect effect through a decrease in risky consumption which has an ambiguous sign.

Result 6 *Other things being equal, in a coordinated union with a higher safe energy price in country* i, $i = 1, 2$ *the other country* $j \neq i$ *is worse off. Also, a country's welfare decreases with the local default probability. The effects of the other exogenous parameters are ambiguous.*

5.4 Welfare analysis

In this section we study the welfare outcomes of different constellations. The purpose is to see whether any union constellation is always preferable to the others. We start by comparing the two union constellations to the outcome of the autarkic equilibrium. Then we proceed with a comparative welfare analysis of the coordinated vs. uncoordinated union.

Unions vs. autarky. The possibility of mutual redistribution in risky states of nature provides the member countries with insurance against uncertainty and helps to smoothen their energy consumption. Therefore it is natural to expect that a union would increase the welfare of the member countries, at least in a completely symmetric case when both countries have identical preferences about the redistribution rule. Indeed, the revealed preference argument suggests that the welfare of countries in a symmetric uncoordinated union exceeds the welfare in an autarky (since country 1 can always choose zero redistribution converting the union into an autarky). In a coordinated union the social planner maximizes joint utility, which in a symmetric case is equivalent to the utility maximization of each of the member countries. The same revealed preference argument implies that a symmetric coordinated union also entails higher utility levels than in the autarky. These results are illustrated by the numerical simulation in column (1) of Table 10. This simulation gives the welfare outcomes of all 3 constellations in the symmetric case when the countries' energy budget is 10, the price of safe energy in each country is $5/4$, the probability of facing unilateral default is $3/16$ and the probability of a "double-default" is $1/16$.

By continuity of the utility function, both a coordinated and uncoordinated union also welfare-dominate the autarky when asymmetry is low. However, as asymmetry increases, being in a union may become

Table 10. Welfare for Different Union Constellations (numerical simulations)

Countries' symmetry		**YES**	**NO:** Higher safe energy price		**NO:** Local default more likely		
			in country 2	in country 1	in country 2	in country 1	
			$p_{s_1} < p_{s_2}$	$p_{s_1} > p_{s_2}$	$a_{dn} < a_{nd}$	$a_{dn} > a_{nd}$	
		(1)	(2)	(3)	(4)	(5)	(6)
Parameters (B=10)	a_{nd}, a_{dn}, a_{dd}	$\frac{3}{16}, \frac{3}{16}, \frac{1}{16}$	$\frac{3}{16}, \frac{3}{16}, \frac{1}{16}$	$\frac{3}{16}, \frac{3}{16}, \frac{1}{16}$	$\frac{3}{16}, \frac{1}{16}, \frac{1}{16}$	$\frac{1}{16}, \frac{3}{16}, \frac{1}{16}$	$\frac{1}{32}, \frac{3}{16}, \frac{1}{16}$
	p_{s_1}, p_{s_2}	$5/4, 5/4$	$25/24, 5/4$	$5/4, 25/24$	$5/4, 5/4$	$5/4, 5/4$	$5/4, 5/4$
Autarky, $\lambda = 0$	W_1^A	8.08	9.6032	8.08	8.16	8.08	8.08
	W_2^A	8.08	8.08	9.6032	8.08	8.16	8.2133
	$W_1^A + W_2^A$	16.16	17.6832	17.6832	16.24	16.24	16.2933
Uncoordinated union	λ^{UU}	0.3772	0.0365	0.9515	0.3474	0.5380	0.8170
	W_1^{UU}	8.1187	9.6033	8.2835	8.2021	8.1322	8.1875
	W_2^{UU}	8.1187	8.0845	8.7557	8.1215	8.1604	7.7856
	$W_1^{UU} + W_2^{UU}$	16.2374	17.6878	17.0392	16.3236	16.2926	15.9731
Coordinated union, $\lambda = 1/2$	W_1^{CU}	8.128	9.5683	8.1649	8.2105	8.1308	8.1408
	W_2^{CU}	8.128	8.1649	9.5683	8.1308	8.2105	8.2432
	$W_1^{CU} + W_2^{CU}$	16.256	17.7332	17.7332	16.3413	16.3413	16.384

a burden. For example, in an uncoordinated union the member that has a leverage over the choice of λ (country 1 in our setting) may prefer much more redistribution than the other member. As a result, the free-riding introduced by the mutual insurance becomes increasingly costly for the member that does not decide on λ. So at some point this member may actually lose out from being in an uncoordinated union. The simulations in columns (5) and (6) in Table 10 illustrate this point. Here, all of the asymmetry between the countries comes from the probability of facing a unilateral default. In column (5) the respective probability is 3 times higher for country 1 than for country 2 (3/16 vs. 1/16). This asymmetry is not sufficiently large yet to overcome the positive effect of an access to the mutual insurance - each country benefits from being in an UU. However, when the asymmetry increases so that country 1 becomes 6 times more likely to face a local default than country 2 (3/16 vs. 1/32), the welfare of country 2 falls short of the autarkic level.

Similarly, if countries differ a great deal, we cannot be certain that a coordinated union will be welfare-enhancing for both members. The reason for this is as follows: the redistribution rule in a coordinated union is always set at $\lambda^{CU} = 1/2$. If countries are sufficiently asymmetric, it may well be the case that one of them prefers more redistribution than in a CU ($\lambda_1 > 1/2$), while the other prefers much less ($\lambda_2 > 1/2$). For the first country being in a coordinated union is always better than staying in an autarky, because the union membership enables it to get closer to its best preferred redistribution rule. For the second country $\lambda^{CU} = 1/2$ may or may not be preferred to the zero redistribution in the autarky case. For example, if the asymmetry is strong, the second country may end up losing from the obligation to cover the losses of a more risk-exposed partner. This situation is illustrated in column (2) of Table 10. Country 2 faces expensive safe energy and as a result consumes a lot of risky energy. In a coordinated union country 1 is forced to compensate this consumption which reduces its welfare below the autarkic level. The symmetric situation (with country 2 suffering from being in a union) is presented in column (3).

Obviously, the question is what makes this member stay in the union.

First the institutional structure may allow for side payments. In this case the social planner of the coordinated union may always compensate the "loser" by arranging a transfer from the "winner". Indeed, as the social planner maximizes the joint countries' welfare, the sum of two welfares in a CU will be always higher than in an autarky,

$$W^*_{CU,1} + W^*_{CU,2} > W^*_{A,1} + W^*_{A,2},$$

so such a redistribution will always be possible. However, this is not necessarily the case for an uncoordinated union as long as the leading country does not take the possibility of side payments into account while making its decisions. If one of the member countries has the power to set the redistribution rule, it may abuse this power so much that the sum of the welfare of two member countries in an UU falls short of that one in an autarky

$$W^*_{UU,1} + W^*_{UU,2} < W^*_{A,1} + W^*_{A,2}.$$

An example of such an outcome is presented in columns (3) and (6) of Table 10. In such a situation no side payments would induce one of the countries to enter the union. If the leading country takes the possibility of side payments into account, it may overcome this situation. The way to do so would be to maximize the joint welfare (given the second stage behaviour) and then compensate the other country to the exact autarkic welfare level.

Also, if the decision to enter the union can be conditioned on redistribution rule λ, country 1 may always ensure the participation of country 2 by choosing such a redistribution rule that provides country 2 with the exact level of autarkic welfare (plus $\varepsilon > 0$). This weakens country 1's decision-making power over λ but it is still beneficial for country 1 due to the possibility of mutual insurance. For example, the cases corresponding to Columns (3) and (6) of Table 10 would take the form presented in Table 11. Indeed, while the entire union now improves over the autarkic outcome (as measured by the sum of two welfares), country 1's gain from mutual insurance is now much less than in corresponding columns of Table 10 since country 1 now has to ensure country 2's participation in the union. The same arrangement can be used in a coordinated union if the side payments are non-feasible or too costly to make.

Table 11. Welfare Outcomes In the Case Union Participation Decision Can Be Conditioned on λ

Countries' symmetry	**NO:** Higher safe energy price in country 1	**NO:** Local default more likely in country 1
	$p_{s_1} > p_{s_2}$	$a_{dn} > a_{nd}$
	(3')	(6')
Parameters (B=10)		
a_{nd}, a_{dn}, a_{dd}	$\frac{3}{16}, \frac{3}{16}, \frac{1}{16}$	$\frac{1}{32}, \frac{3}{16}, \frac{1}{16}$
p_{s_1}, p_{s_2}	$5/4, 25/24$	$5/4, 5/4$
Autarky, $\lambda = 0$		
W_1^A	8.08	8.08
W_2^A	9.6032	8.2133
$W_1^A + W_2^A$	17.6832	16.2933
Uncoordinated union		
λ^{UU}	0.06946	0.48299
W_1^{UU}	8.0889	8.1485
W_2^{UU}	9.6032	8.2133
$W_1^{UU} + W_2^{UU}$	17.692	16.362

Finally, the countries may choose to stay in the union even if they lose from being part of the mutual insurance agreement if there are other benefits from joining the union, or other costs from staying outside it. We return to this question in the discussion in section 5.5.

Coordinated vs uncoordinated unions. Now we turn to the comparative welfare analysis of two union constellations. In an uncoordinated union each country ignores the negative impact of an increase in its own "risky" energy consumption on the partner's welfare. Therefore, for the same redistribution rule each country consumes too much "risky" energy in equilibrium as compared to the socially optimal level Obviously this also has an impact on the choice of λ at the first stage of the game. Therefore the joint welfare is always lower in an uncoordinated union than in a coordinated one.

$$W^*_{UU,1} + W^*_{UU,2} < W^*_{CU,1} + W^*_{CU,2}. \tag{12}$$

Again, whether or not each country loses as compared to the first best outcome of a CU is unclear and depends on the asymmetry between the countries. Typically we would expect the country that is setting the policy in an uncoordinated union to lose less or even to gain if the asymmetry is sufficiently high (like in columns (2), (3), (5) and (6) of Table 10). However equation (12) suggests that at least one country always loses in an uncoordinated union as compared to the socially optimal case of a coordinated union.

We summarize the discussion of this section in the following result.

Result 7 (Welfare Comparison) *Assume that union participation is given.*

a. If the institutional setting allows side payments, the coordinated union welfare-dominates the other constellations. If the leading member takes into consideration the possibility of side payments, an uncoordinated union is better than an autarky. If the leading member does not account for side payments, the welfare ranking between the uncoordinated union and the autarky is ambiguous and depends on the asymmetry between the union members.

b. In the absence of side payments the autarkic outcome may be preferred to the union constellations by one (and only one) country if the asymmetry between the countries is sufficiently high.

One of the questions raised by our analysis concerns possible measures a union can undertake to correct the negative externality resulting from the mutual insurance. To put it differently, what economic mechanisms can be implemented by the union to improve coordination among its members? The standard approach suggests imposing so called "Pigouvian" tax that would lower the consumption or production of the good associated with externality and, thus, improve efficiency. In our case such a tax would be levied on risky energy consumption. However, "Pigouvian" tax may be insufficient to improve the situation, if the power is unequally distributed within the union and the union members are sufficiently asymmetric. The reason is that "Pigouvian" tax aims at correcting inefficiency in risky energy consumption but does not have sufficient power to correct inefficiencies in the choice of the redistribution rule. When the asymmetry between the countries is strong, the leading member may choose the redistribution rule that benefits him at the cost of the other members, and the presence of "Pigouvian" tax will not compensate for this inefficiency. This suggests a need to study further possible mechanisms to improve coordination and achieve efficiency within the union, which is however beyond the scope of this report.

5.5 Risky energy consumption as an efficiency measure

We have seen above that for the same redistribution rule an uncoordinated union overconsumes risky energy. How general is this conclusion? Should we necessarily expect the absence of coordination to lead to the overconsumption of risky energy? Or, to put it differently, we know that free-riding in the uncoordinated union leads to it being welfare-dominated by a CU, at least in the presence of transfers. Does this imply that more risky energy is always worse for social welfare? Can we use risky energy consumption as a proxy for the effectiveness of collaboration within a union? In this section we aim to answer this question by comparing the risky energy consumption in an uncoordinated and a coordinated union.

With the same redistribution rule λ the consumption of risky energy in an UU is always higher than in a CU due to the moral hazard effect. However, consider the case of sufficiently high asymmetry between the countries. In particular let country 2 be much more exposed to risks/risky energy than country 1. In this case country 1, being the decision-maker in an uncoordinated union, chooses lower redistribution than the one of a coordinated union to avoid high moral hazard costs. As the consumption of risky energy in the uncoordinated union increases with λ, the final effect is unclear.

Table 12. Risky Consumption of Different Union Constellations (numerical simulations)

Countries' symmetry	**YES**	**NO:** Higher safe energy price	
		in country 2	in country 1
		$p_{s_1} < p_{s_2}$	$p_{s_1} > p_{s_2}$
	(1)	(2)	(3)
Parameters (B=10)			
a_{nd}, a_{dn}, a_{dd}	$\frac{3}{16}, \frac{3}{16}, \frac{1}{16}$	$\frac{3}{16}, \frac{3}{16}, \frac{1}{16}$	$\frac{3}{16}, \frac{3}{16}, \frac{1}{16}$
p_{s_1}, p_{s_2}	$5/4, 5/4$	$25/24, 5/4$	$5/4, 25/24$
Uncoordinated union			
λ^{UU}	0.3772	0.0365	0.9515
r_1^{UU}	1.4790	0.16909	3.1776
r_2^{UU}	1.4790	0.84544	0.63552
Coordinated union, $\lambda = 1/2$			
r_1^{CU}	1.28	0.256	1.28
r_2^{CU}	1.28	1.28	0.256

When λ^{UU} exceeds λ^{CU}, the consumption of risky energy is clearly higher in an UU than in a CU. In this case both effects work in the same direction: both the free-riding incentive and the higher λ boost risky energy consumption in an UU. This outcome is supported by the simulations in column (3) of Table 12.

When λ^{UU} is lower than $\lambda^{CU} = 1/2$ but not too different from λ^{CU}, the free-riding effect of increasing the risky energy consumption at the expense of the other party exceeds the negative effect on the risky energy consumption coming from underinsurance (= lower λ). Indeed, in this case the countries are not too different and nor are their preferred risky energy consumption levels. So country 1 is willing to set a relatively high λ. This outcome is illustrated by column (1) of Table 12. But when λ^{UU} is significantly lower than $\lambda^{CU} = 1/2$, the risky energy consumption of an UU may fall short of the risky energy consumption of a CU. In this case the threat of country 2 abusing mutual insurance is very strong and country 1 will try to protect itself by suppressing redistribution rule λ. This, in turn, forces down not only the risky energy consumption of country 2 (as intended), but also the risky energy consumption of country 1. An illustration of such an outcome is presented in column (2) of Table 12.

For example, if all of the asymmetry comes from the prices of safe energy (like in Table 12), we obtain the following result.

Result 8 (Risky energy consumption) *Assume that the countries are exactly symmetric in terms of shocks and the price of safe energy in country 1 is lower than the price of safe energy in country 2. For each set of shock probabilities there exists a pair of safe energy prices* (p_{s_1}, p_{s_2}) *such that the risky energy consumption in an UU is below that of a CU for both country members.*

$$r_i^{UU} < r_i^{CU}. \tag{13}$$

Moreover, for the same p_{s_1}, *the higher the ratio of the probability of a local default to the probability of double default* a_{nd}/a_{dd} *is, the higher the price of country 2's safe energy* p_{s_2}*could be for effect (13) to still take place.*

The first part of this result states that if the asymmetry between the countries is high enough, country 1 will always choose a sufficiently low λ so that the moral hazard effect will be reduced by this fall in λ. The intuition behind the second part of this result is as follows: We start in a situation where the risky consumption in an UU is below that of a CU. As the ratio of probability of unilateral default to the probability of the double default increases, bailing out country 2 (that faces higher safe energy prices) becomes more costly for country 1. As a result, country 1 tries to protect its welfare by lowering λ^{UU}, which in turn lowers the risky consumption as compared to the CU. A slight increase in the price of risky energy in country 2 is not sufficient to revert the result.

To summarize, countries staying in an uncoordinated union consume an inefficient amount of risky energy, but it should not necessarily be above the optimal level of a coordinated union. In other words, a common energy policy targeted to improve the security of energy supply should not necessarily imply limiting energy consumption from risky sources. With adequate coordination, more (cheap) risky energy may actually improve efficiency.

5.6 Formation of the union

We have seen that when countries are sufficiently asymmetric, country 2 may lose from being part of the mutual insurance agreement when country 1 chooses its best-preferred redistribution rule. The question that we address now is whether these outcomes can be sustained in a union in the setting with no institutional possibility for side payments. In other words, could we observe the formation of a union with the 1st country implementing its best-preferred choice of redistribution rule λ and the second country only achieving a welfare level below the autarkic one?

As stressed above, this situation is only possible if staying outside the union imposes certain costs on the non-members or, alternatively, if membership of the union is associated with some additional benefits. Clearly, there are many ways in which a union may provide extra gains to members or be detrimental to outsiders. The formation of a union may cause its members to divert collaboration efforts from the non-member countries. For example, a country joining a union may create a common infrastructure with the union members, leaving behind countries outside the union. In other words, union outsiders may be adversely affected by the existence of the union. This may provide them with incentive to join the union even in the absence of direct benefits of mutual insurance against energy risks.[24]

At the same time, a union created to achieve higher energy security may improve coordination among its members, which, in turn may lower the transaction costs in different areas of economic activity, such as trade. In this case, an "energy union" membership would yield some benefits beyond the field of energy security.

[24] See Dixit (2003) for a relevant discussion.

It could also be the case that the institutional structure of the union "links" several issues on the agenda. In this case the union members may compensate the losses along one agenda dimension with the gains along other dimensions. This argument works even if the union only covers the issues related to the energy security.

More precisely, suppose that countries consume two types of energy, say, oil and gas. For each energy, type the market is identical to the model above, with "safe" and "risky" energy suppliers, the latter being associated with occasional defaults. Assume further that the countries are unable to reach separate agreements on the union status for each energy type. That is, either the countries operate in an autarky, or they insure each other for *both* types of energy. We also keep the assumption that country 1 is the agenda setter for both types of energy.

Suppose that in the gas market there is a strong asymmetry between the countries: country 1 prefers a lot of redistribution, while country 2 prefers just a bit. For example, country 1 has neither any indigenous gas production nor an easy access to the safe gas producers, while country 2 produces gas domestically. As we have seen above, in this case country 2 may lose from joining the union. In other words, country 2 may have higher utility in autarky than under a mutual insurance scheme with country 1's best preferred redistribution rule. However, the asymmetry between the countries does not need to be correlated for different types of energy. It could well be the case that country 1 faces a relatively greater risk in the gas market (as compared to country 2), while their positions in the oil market do not differ much. Moreover, the direction of asymmetry may be reversed, with country 2 facing higher risks and preferring more redistribution. This implies that country 2 benefits from joining the union in the oil market. In this case country 2 may indeed decide to join the union even if it loses in the gas market.

Example 4 (Uncorrelated Assymetry for Different Energy Types) *According to our classification in section 3.3, Germany contributes one of the highest shares to the EU risk of external gas supply with CERE_gas=21%, while the Netherlands has one of the strongest positions in the gas market contributing nothing to the European risk*

with CERE_gas=0%. (This is due to the fact that it is the second largest gas producer in Europe). At the same time, their positions with respect to the security of external oil supply differ much less: here Germany has a CERE_oil index of 17%, and the Netherlands 8%.
The argument of the absence of systematic asymmetry becomes even stronger if one instead relies on the REES index. The relative risk position of these two countries as regards gas consumption is the reverse of the one for oil. In the gas market Germany is relatively more exposed to risk with REES_gas=2.8, while the Netherlands has REES_gas=0.0. As concerns the external supply of oil the situation is inverted: the Netherlands faces a higher risk with REES_oil=5.6 compared to a more moderate risk for Germany with REES_oil of 3.3.

Obviously, if it were possible to have separate memberships, country 2 would choose to join the union in the oil market (which improves its welfare) but to remain outside the union in the gas market (which imposes costs on country 2). However, under our assumption, union membership cannot be conditioned on the policy issue. Therefore, if the benefits from mutual insurance in the oil market are sufficiently high to compensate for the losses in the gas market, country 2 would choose to join the union.

Therefore the unconditional membership rule yields an additional bargaining power to the agenda setter (in our example, country 1). The unconditional membership allows the agenda setter to trade off the benefits of one union against the costs of the other, which relaxes the participation constraints of country 2. This, in turn, leads to redistribution of welfare within the union from country 2 to country 1, which may not be politically desirable.

How would one ensure an adequate and fair balance within the union? One way to limit the leverage of country 1 would be to allow for separate memberships. In other words, there could be some advantage in designing unrelated common policy rules for different energy types. This may help to improve the "fairness" within the union. To some extent this is the approach currently followed by the European

Union, for example, in setting separate storage requirements for gas and oil. However, this may lead to some efficiency losses as linked agenda issues in some cases facilitate policy cooperation (e.g. see Spagnolo (1999) or Horstmann et al (2001)).

Probably a better way to keep the balance within the union would be to allocate the agenda setting power on different issues to different union members. In this case integrating policy on different energy types may be beneficial. An integrated union would limit the selfish behaviour of an agenda setter on each separate energy issue. Indeed, a non-cooperative decision of such an agenda setter would be punished by the agenda setters in other areas covered by the union (compare to Maggi (1999)). As long as the power within the union is reasonably spread out, one may expect an integrated union to outperform the collection of unions on each separate energy type.

5.7 A better balanced union

So far we have assumed that country 1 always has full bargaining power as regards the determination of the mutual insurance rule in an uncoordinated union. How important is this assumption for the conclusions of the model? In this subsection we address the implications of relaxing the "leading country" assumption.

Assume that the union is more balanced, i.e., the bargaining power over the energy policy is more evenly allocated. While the partial comparative statics results stay the same, the full comparative statics results are likely to be affected. The way policy rule λ and the union members' welfare respond to the change in the exogenous model parameters, such as safe energy prices and default probabilities, will depend on the relative bargaining power in the union and may well be ambiguous. Also, since both countries have an impact on the common energy policy the welfare gains of mutual insurance should be redistributed more evenly. In particular, situations in which one of the union members loses compared to the state of autarky become less likely. However, the main predictions of the welfare analysis do not change much, because a better balance within the union does not eliminate the moral hazard problem. As a result, the joint outcome of a coordinated union still dominates over the one of an uncoordinated union, which, in turn, outperforms the autarky. Moreover, for a sufficiently symmetric allocation of bargaining power this result is likely to hold for each of the union members. This implies that even with complete parity within the union there is still a strong call for improving union coordination.

Now let us turn to risky energy consumption as an efficiency measure. A more even allocation of the bargaining power within the union also implies that the mutual insurance rule is not likely to be extreme. In the original model, a high λ resulted from country 1 being much more affected by risks than country 2. Similarly, a low λ was an outcome of country 1 being unwilling to share the stronger risks affecting country 2. Now, even in the case of strong asymmetry between the union members they jointly influence the mutual insurance rule, which yields more moderate levels of λ. This implies that the situations with a low λ become less frequent. As a result, the risky consumption in an UU is more likely to exceed the one of a CU, i.e., the risky consumption in a more balanced union is a better reflection of union performance. However, one still has to be careful in using the risky consumption as an efficiency measure. Other things being equal, at each point in time a higher risky energy consumption of some union members may indeed reflect their susceptibility to external energy shocks. However, the time evolution of this variable may reflect not only a change in the degree of coordination within the union but also the reallocation of the bargaining power. In other words, a lower risky consumption may correspond to a better coordinated union as well as a shift in the bargaining power to the member who is less exposed to energy risks. Therefore, in analyzing union performance over time one also needs to account for certain institutional characteristics.

Part IV

CONCLUSIONS AND POLICY IMPLICATIONS

This report addresses the security of supply aspects of a common energy policy in the European Union. A common energy policy can benefit the Member States by ensuring the security of supply through the increased solidarity among the Member States. At the same time a common energy policy may also impair the states' welfare by creating a moral hazard problem. The report suggests a new approach to quantifying the security of external energy supply and provides a formal treatment of the moral hazard problem caused by a common energy policy.

Summary of the results. Based on the previous approaches in the literature, the report proposes a new set of indexes measuring the risks associated with the external supply for different energy types. It argues that these indexes are better suited for capturing the short-term energy supply risks associated with foreign suppliers. These indexes take into account the energy consumption structure of the consuming country, the risks associated with the supplying country and the transport of energy as well as the relative impact of different EU members on the aggregate energy risk in the EU. It also shows that the risk exposure and risk ranking among the EU members differ for different energy types.

The formal analysis in the report addresses the costs and benefits associated with a particular aspect of a common energy policy, the solidarity that results in a mutual insurance mechanism. When countries face several energy suppliers with different degrees of riskiness, they trade off prices and risk to build an "energy portfolio". If countries decide to form a union with a common energy policy, they can insure each other against the local shocks by redistributing energy between the member countries. This smoothens energy consumption's shocks of each individual member and allows countries to consume more of the cheap risky energy. Therefore, if the countries' decisions are perfectly coordinated, a union is an improvement over an autarky. Whether or not each individual country is better off, depends on the degree of asymmetry in the union. If countries are identical, they both gain from joining the union, while if there is a sufficiently strong asymmetry between the countries, some of the countries may lose. In order to insure that the welfare of each member increases, one needs to establish a transfer mechanism that will allow side payments from the winners to the losers. However, the mutual insurance opportunity creates free-riding incentives and results in a moral hazard problem. If countries do not account for negative externalities they impose on the others members through their risky consumption (i.e., they are in an uncoordinated union), they tend to purchase inefficiently high volumes of risky energy. To lower the costs associated with the increased exposure to risks, the agenda setting members of the union react by adjusting the mutual insurance rule, which escalates the inefficiency. As a result, at least one of the members of an uncoordinated union definitely loses as compared to the case of perfect coordination and may, under some circumstances, lose even as compared to an autarky. The possibility of transfers allows the uncoordinated union to be an improvement as compared to the autarkic outcome, but the coordinated union still welfare-dominates.

A common energy policy union may form even if one of its members is worse off than in an autarky. Clearly this outcome only takes place if there are additional benefits from being a member of the union or costs from staying outside it. For example, a common energy policy may link different types of energy to the same agenda. As shown in the discussion on the risk indexes, countries may have different relative risk positions for different energy types. In this case a loss within one type of energy can be compensated by the gain from being part of the mutual insurance agreement on the other energy type. However, such a linkage may cause a shift of welfare within the union towards its more powerful members, which may be undesirable from a policy perspective.

The modelling framework suggests also that risky energy consumption is an imperfect measure of the security of energy supply, at least from the efficiency perspective. Indeed, a superficial view of the moral hazard problem created by the solidarity within an uncoordinated union would suggest that, other things being equal, the risky energy consumption is always higher in an uncoordinated union than in a coordinated union. Therefore one could rely on the risky consumption as an observable criterion of the efficiency of a common energy policy. However, this logic is misleading. The report shows that the countries in an uncoordinated union indeed consume an inefficient amount of risky energy, but the level may be lower than the one of a coordinated union. This effect comes through the adjustment in the mutual insurance rule. For example, if the country that has more leverage over the common energy policy is less affected by risks than the other member, it lowers the mutual insurance coverage. This allows to cut the mutual insurance costs it bears as it decreases risky consumption of the other member. For sufficiently high asymmetry between the countries this decrease in risky energy consumption may dominate the free-riding overconsumption effect. In this case the risky consumption in the uncoordinated union falls short of the one in the coordinated union.

Policy Implications. There are several policy implications based on the discussion in the report. First, the energy security index results suggest that one needs to rely on a more *sectoral approach* in quantifying the short-term external energy risks. Since the short-term substitution among different types of energy is problematic or very costly, an aggregate risk index may be too imprecise to evaluate the potential damage caused by a supply disruption in a specific energy market. The sectoral estimates of risk would provide a more reliable base for such an evaluation. Similarly, since the countries' energy risks may differ for different energy types, supply security may require different policy tools for each type, which again can only be determined with the help of a sectoral approach.

The welfare analysis in the model implies that there is a need for establishing a *strong regulatory agency* that would coordinate the actions of individual country members and make them obey the jointly developed rules. This coordination would improve the efficiency of a common energy policy. If the creation of such an agency is impossible or very costly, one should seriously consider the potential costs of implementing a common policy. This echoes the European Commission proposal to create an Agency for the Cooperation of Energy Regulators (ACER), with the main task of ensuring cooperation between national regulators and between transmission system operators (European Commission, 2007). Interestingly, this proposal mentions that the agency would have “individual decision power” and would "decide on the regulatory regime applicable to infrastructure within the territory of more than one Member State”. This might be regarded as the desire of the EU to create an agency with strong coordination power.

In addition, the discussion on union membership suggests that to provide a more balanced distribution of common energy policy gains within the union one needs to control for a reasonably *equal allocation of the policy setting power*. The allocation of bargaining power over separate energy issues to different union members would restrain the discretion of each agenda setter and induce more cooperation within the union, benefitting all its members. The European Union seems to target this objective through the rotating Presidency practice, however, more effort is needed to ensure more equal power allocation. An alternative approach to improve the fair balance within the union would be unlinking different energy issues. However, this approach provides a second best option as it may cause an efficiency loss compared to the integrated union with dispersed bargaining power.

Finally, the argument on the risky energy consumption being uncorrelated with union efficiency also has an obvious policy implication: A common energy policy aimed at improving the security of energy supply does not need to be too restrictive on risky energy consumption. With adequate coordination, more (cheap) risky energy may be efficiency-enhancing. In other words, *risky energy consumption may not be a good measure of union performance*. This caution is especially relevant in analyzing the development of the situation with risky energy consumption over time. This means that, within a given union at each point in time a higher risky consumption of some members may indeed be a sign of greater energy security vulnerability. However an evolution of risky consumption over time may be affected by the degree of coordination within the union and does not need to reflect the risk exposure. Therefore, one needs to rely on additional measures of the institutional structure and the welfare of union members when judging the effect of a particular common energy policy aspect.

Extensions. This report can be extended in several directions. The security supply index can be extended to account for longer-term reaction to energy supply risks. The modelling framework can be modified to formally model the dynamic aspects of a common energy policy and the related moral hazard problems. One can formally study the union creation and union participation decisions, as well as different decision rules governing the common energy policy within the union. Moreover, a common energy policy may have an impact on the bargaining power between the union members and the risky producer. The possibility of coordinating decisions may improve the union members' bargaining power and thus lower the risky energy price. This would provide an additional benefit of joining a common energy policy agreement. Finally one can study possible mechanisms to achieve better coordination within the union.

REFERENCES

[1] Alesina A, I. Angeloni and F. Etro, (2005), "International Unions", American Economic Review, vol. 95(3), pages 602-615.

[2] Baltic Business News, 12.07.2007, "Russian-German gas pipeline is vitally important" at http://www.balticbusinessnews.com/newsletter/070712_-bbn_newsletter.pdf.

[3] Berglof, E., M. Burkart, G. Friebel and E. Paltseva, (2007), "Club-in-the-Club: Reform under Unanimity", ECGI Finance Working Paper 149/2007.

[4] Berglof, E., M. Burkart, G. Friebel and E. Paltseva, (2008), "Widening and Deepening: Reforming the European Union", mimeo.

[5] Besley, T. and S. Coate, (2003),. "Central versus local provision of public goods: a political economy analysis.", Journal of Public Economics 87, no. 4, pp. 2611-2637.

[6] Blyth W. and N. Lefevre, (2004), "Energy Security and Climate Change", International Energy Agency Information Paper.

[7] De Jong, J., H. Maters, M. Scheepers and A. Seebregts, (2007), "EU Standards for Energy Security of Supply", ECN-E-07-004/CIEP.

[8] Dixit, A., (2003), “Clubs with Entrapment”, American Economic Review, 93 (5), pp. 1824-1829.

[9] Egenhofer, C. and T. Legge, (2001), "Security of Energy Supply: A question for policy or the markets?",CEPS Task Force Report.

[10] European Commission, (2000), "Towards a European Strategy for the Security of Energy Supply", Green Paper, COM(2000) 769 final.

[11] European Commission, (2004a), "Energy and Transport 2000-2004", Report published by the European Commission, Directorate-General for Energy and Transport, at http://europa.eu.int/comm/dgs/energy_transport.

[12] European Commission, (2004b), “The Lisbon Strategy”, at http://europa.eu.int/comm/lisbon_strategy/index_en.html.

[13] European Commission, (2006a), "An External Policy to Serve Europe’s Energy Interests", Paper from Commission/SG/HR for the European Council, 15-16 June, S160/06, Brussels.

[14] European Commission, (2006b), Green Paper of 8 March 2006: "A European strategy for sustainable, competitive and secure energy", COM(2006) 105.

[15] European Commission, (2006c), "Towards a European Strategy for the Security of Energy Supply", Green Paper on Energy Security, Technical Document, Brussels at http://europa.eu.int/comm/energy_transport/doc-technique/doctechlv-en.pdf.

[16] European Commission, (2007), "An Energy Policy for Europe", Communication from the Commission to the European Council and the Parliament, SEC(2007) 12, Brussels.

[17] European Council, (2007), Presidency Conclusions, 7224/1/07 REV1, Brussels.

[18] European Parliament, (2001), "Report on the Commission Green Paper towards a European strategy for the security of energy supply" COM(2000) 769 final - C5 - 0145/2001/2071(COS)), Committee on Industry, External Trade, Research and Energy, 17 October, Rapporteur: Giles Chichester.

[19] European Parliament and the Council, (1996), "Directive concerning common rules for the internal market in electricity", 96/92/EC.

[20] European Parliament and the Council, (1998), "Directive concerning common rules for the internal market in natural gas", 98/30/EC.

[21] Geden O., C. Marcelis and A. Maurer, (2006), "Perspectives for the European Union's External Energy Policy: Discourse, Ideas and Interests in Germany, the UK, Poland and France", SWP-Working Paper FG 1 2006/17, Berlin, Dec 2006.

[22] Fecht F. and H. Grüner, (2005), "Financial Integration and Systemic Risk", Deutche Bundesbank Discussion Paper #11/2005.

[23] Finon D. and C. Locatelli, (2007), "Russian and European gas interdependence. Can market forces balance out geopolitics?", mimeo.

[24] Helm, D., (2005), "European Energy Policy: Securing supplies and meeting climate the challenge of climate change", Oxford, mimeo.

[25] Hedenskog J. and R. L. Larsson, (2007) Russian Leverage on the CIS and the Baltic States, FOI-R–2280–SE.

[26] Horstmann I. J., J. R. Markusen and J. Robles, (2001), "Multi-Issue Bargaining and Linked Agendas: Ricardo Revisited or No Pain No Gain," NBER Working Papers 8347, National Bureau of Economic Research.

[27] Ihori T. and M. McGuire, (2006) "Group Provision Against Adversity: Security By Insurance vs. Protection", CIRJE Discussion Paper.

[28] International Energy Agency, http://www.iea.org/.

[29] Jansen J.C., W.G. van Arkel, and M.G. Boots, (2004) "Designing indicators of long-term energy supply security", Energy research Centre of the Netherlands, ECN-C–04-007.

[30] Keppler J.H., (2007), International Relations and Security of Energy Supply: Risk to Continuity and Geopolitical Risks, Mimeo, IFRI.

[31] Luciani, G., (2004) "Security of Supply for Natural Gas Markets. What is it and What is it not?", FEEM Working Paper No. 119.04.

[32] Maggi G., (1999), "The Role of Multilateral Institutions in International Trade Cooperation", American Economic Review, Vol. 89, No. 1, pp. 190-214.

[33] Markandya, A., and A. Hunt, (2004), "The Externalities of Energy Insecurity",ExternE-Pol, Externalities of Energy: Extension of Accounting Framework and Policy Applications, Final Report.

[34] Neumann, A., (2004), "Security of Supply in Liberalised European Gas Markets". Diploma Thesis, European University Viadrina.

[35] Neumann, A., (2007), "How to measure security of supply?", mimeo, Dresden University of Technology.

[36] Persson, T. and G. Tabellini, (1996), "Federal Fiscal Constitutions: Risk Sharing and Moral Hazard", Econometrica, Vol. 64, No. 3, pp. 623-646.

[37] Political Risk Group, http://www.prsgroup.com/.

[38] Röller, L.H., J. Delgado and H.W. Friederiszick, (2007) "Energy: Choices for Europe", Bruegel Blueprint Series.

[39] Spagnolo, G., (1999), "Issue Linkage, Delegation, and International Policy Cooperation", mimeo.

[40] Stern, J., (2006) "The New Security Environment for European Gas: Worsening Geopolitics and Increasing Global Competition for LNG", Oxford Institute for Energy Studies NG 15.

[41] Tallberg J. (2007), "Bargaining Power in the European Council", SIEPS report 2007:1.

[42] Van der Linde, C., (2007) "External energy policy: Old fears and new dilemmas in a larger Union", in "Fragmented power: Europe and the global economy", André Sapir (ed.), Bruegel.

[43] Van der Linde, C., M. P. Amineh, A. Correljé and D. de Jong, (2004), Study on Energy Supply Security and Geopolitics, CIEP Report, Study on Energy Supply Security and Geopolitics, Clingendael International Energy Programme, The Hague.

[44] Zweifel, P. and S. Bonomo, (1995), "Energy security Coping with multiple supply risks," Energy Economics, Elsevier, vol. 17(3), pp. 179-183.

Part V

APPENDIX

A.1. Interpretation of the Assumption 1

The sum of all four probabilities is

$$\sum_{k,l\in\{n,d\}} a_{kl} = 1,$$

since they cover all possible states of nature. The probability of country 1 facing a default is given by the sum of a_{dn} and a_{dd}. Similarly, the probability of country 2 facing a default is given by the sum of a_{nd} and a_{dd}. If a_{nn} were equal to 0, the sum of the two default probabilities would be

$$\begin{aligned}(a_{nd} + a_{dd}) + (a_{dn} + a_{dd}) &\overset{\|a_{nn}=0\|}{=} a_{nn} + a_{nd} + a_{dn} + 2a_{dd} \\ &\overset{\left\|\sum_{k,l\in\{n,d\}} a_{kl}=1\right\|}{=} 1 + a_{dd} \geq 1.\end{aligned}$$

Therefore at least one of the two default probabilities should be above 1/2 which contradicts our assumption.

A.2. Risky energy demand in an autarky (equations (1) and (2))

Country 1 maximizes

$$\begin{aligned}&\max_{r_1} s_1 + r_1 - \frac{1}{2}\left[(a_{dn} + a_{dd})(r_1)^2\right] \\ &s.to \;\; p_{s_1}s_1 + r_1 \leq B_1\end{aligned}$$

First order conditions with respect to r_1 is given by

$$-\frac{1}{p_{s_1}} + 1 - (a_{dn} + a_{dd})r_1 = 0$$

which yields

$$r_1 = \frac{1 - 1/p_{s_1}}{a_{dn} + a_{dd}}.$$

Risky energy consumption of country 1 is found in the same way.

A.3. Proof of Result 1

Inserting the budget constraint into the utility maximization results in

$$\max_{r_1} \frac{B - r_1}{p_{s_1}} + r_1 - \frac{1}{2}\left[(a_{dn} + a_{dd})(r_1)^2\right]$$

Risky energy consumption is chosen efficiently. Therefore the envelope theorem ensures that the effect of exogenous parameters on welfare is given by the partial derivative with respect to the these parameters, which yields the comparative statics results.

A.4. Risky energy demand in an uncoordinated union (equations (5) and (6))

Country 1 maximizes

$$\max_{r_1} s_1 + r_1 - \frac{1}{2}\left[a_{nd}\left(\lambda r_2\right)^2 + a_{dn}\left((1-\lambda) r_1\right)^2 + a_{dd}(r_1)^2\right]$$
$$s.t.\ p_{s_1} s_1 + r_1 \leq B_1.$$

Inserting the budget constraint into the utility maximization yields

$$\max_{r_1} \frac{B - r_1}{p_{s_1}} + r_1 - \frac{1}{2}\left[a_{nd}\left(\lambda r_2\right)^2 + a_{dn}\left((1-\lambda) r_1\right)^2 + a_{dd}(r_1)^2\right].$$

First order conditions are

$$-\frac{1}{p_{s_1}} + 1 - \left(a_{dn}(1-\lambda)^2 + a_{dd}\right) r_1 = 0.$$

Solving for r_1 we get

$$r_1^{UU}(\lambda) = \frac{1 - 1/p_{s_1}}{a_{dn}(1-\lambda)^2 + a_{dd}}.$$

A.5. Proof of Lemma 1 (Existence of λ)

Being a continuous function of λ, the welfare of country in uncoordinated union, $U_1(s_1, r_1^{UU}, r_2^{UU}, \lambda)$, reaches its maximum on compact set [0, 1]. The derivative of it with respect to λ is positive at $\lambda = 0$

$$\begin{aligned}
& \left.\frac{\partial U_1(s_1, r_1^{UU}, r_2^{UU}, \lambda)}{\partial \lambda}\right|_{\lambda=0} \\
= \; & -\lambda \left(a_{nd} \left(r_2^{UU} \right)^2 + a_{dn} \left(r_1^{UU} \right)^2 \right) \\
& \left. - (\lambda)^2 (1-\lambda) \frac{2a_{nd}^2 \left(r_2^{UU} \right)^3}{\left(1 - 1/p_{s_2} \right)} + a_{dn} \left(r_1^{UU} \right)^2 \right|_{\lambda=0} \\
= \; & a_{dn} \left(r_1^{UU} \right)^2 > 0,
\end{aligned}$$

and negative at $\lambda = 1$

$$\begin{aligned}
& \left.\frac{\partial U_1(s_1, r_1^{UU}, r_2^{UU}, \lambda)}{\partial \lambda}\right|_{\lambda=1} \\
= \; & -\lambda \left(a_{nd} \left(r_2^{UU} \right)^2 + a_{dn} \left(r_1^{UU} \right)^2 \right) \\
= \; & \left. - (\lambda)^2 (1-\lambda) \frac{2a_{nd}^2 \left(r_2^{UU} \right)^3}{\left(1 - 1/p_{s_2} \right)} + a_{dn} \left(r_1^{UU} \right)^2 \right|_{\lambda=1} \\
= \; & -a_{nd} \left(r_2^{UU} \right)^2 < 0.
\end{aligned}$$

In other words, country 1's utility increases at $\lambda = 0$ and decreases as λ approaches 1. As $U_1(s_1, r_1^{UU}, r_2^{UU}, \lambda)$ is a continuous function of λ, the maximum is reached at an interior point of [0, 1] where

$$\begin{aligned}
\Phi(\lambda) \; \equiv \; & -\lambda \left(a_{nd} \left(r_2^{UU} \right)^2 + a_{dn} \left(r_1^{UU} \right)^2 \right) \\
& - (\lambda)^2 (1-\lambda) \frac{2a_{nd}^2 \left(r_2^{UU} \right)^3}{\left(1 - 1/p_{s_2} \right)} + a_{dn} \left(r_1^{UU} \right)^2 \\
= \; & 0.
\end{aligned} \tag{14}$$

That completes the proof of country 1's optimal redistribution rule λ_1^{UU} being given by an interior solution.

Moreover, $\Phi(\lambda)$, being a polynomial function of polynomial fractions r_i^{UU}, is itself a ratio of two polynomials in λ, and the one in the denominator is always positive. Thus the roots of $\Phi(\lambda)$ are determined by the polynomial in the numerator and there could only be a final number of them. As a result, there is a final number of local maxima on (0, 1) which implies that there is a final number of global maxima too.

A.6. Discussion on Assumption 2

Assumption 2 ensures that there is only one local maximum of the first country's utility function $U_1(s_1, r_1^{UU}, r_2^{UU}, \lambda)$ which then also becomes a global maximum. That suggests that the second derivative of $U_1(s_1, r_1^{UU}, r_2^{UU}, \lambda)$ at the maximum point is negative. This requirement is not very demanding. In fact, it demanded a significant effort to find a case that contradicts this requirement. We only provide a sufficient condition for the model's parameters to ensure assumption 2 is satisfied. Then we demonstrate that it holds for countries that are symmetric in terms of default probabilities. Finally we argue that if the asymmetry is not too high, the maximum is still unique. The arguments for country 2 are identical.

Consider the second derivative of $U_1(s_1, r_1^{UU}, r_2^{UU}, \lambda)$ with respect to λ. It is given by

$$
\begin{aligned}
&\partial^2 U_1(s_1, r_1^{UU}, r_2^{UU}, \lambda) \Big/ \partial\lambda^2 \Big|_{extremum} \\
&= a_{dn}\left(1 - \frac{1}{p_{s_1}}\right)^2 \frac{3a_{dn}(1-\lambda)^2 - a_{dd}}{\left(a_{dn}(1-\lambda)^2 + a_{dd}\right)^3} \qquad (15) \\
&- \frac{a_{nd}\left(1 - 1/p_{s_2}\right)^2}{\left(a_{nd}(1-\lambda)^2 + a_{dd}\right)^4}\left[4(a_{nd} + a_{dd})a_{nd}\lambda(1-2\lambda)\right. \\
&\left. + 3a_{nd}^2\lambda^4 + (a_{nd} + a_{dd})^2\right]
\end{aligned}
$$

If we only consider the second derivative in the local extremum (where the first order conditions are satisfied with equality, i.e., equation (14) holds), we can use equation (14) to rewrite the first term in equation (15) as

$$a_{dn}\left(1-\frac{1}{p_{s_1}}\right)^2\frac{3a_{dn}(1-\lambda)^2-a_{dd}}{\left(a_{dn}(1-\lambda)^2+a_{dd}\right)^3}$$

$$=\ \lambda\left(1-\frac{1}{p_{s_2}}\right)^2 *$$

$$*\frac{a_{nd}\left(a_{nd}\left(1-\lambda^2\right)+a_{dd}\right)\left(3a_{dn}(1-\lambda)^2-a_{dd}\right)}{\left(a_{nd}(1-\lambda)^2+a_{dd}\right)\left(a_{dn}(1-\lambda)^2+a_{dd}\right)(1-\lambda)}.$$

The entire expression (15) thus takes the following form:

$$\partial^2 U_1(s_1,r_1^{UU},r_2^{UU},\lambda)\Big/\partial\lambda^2\Big|_{extremum}$$

$$=\frac{\lambda\left(1-\frac{1}{p_{s_2}}\right)^2 a_{nd}\left(a_{nd}\left(1-\lambda^2\right)+a_{dd}\right)\left(3a_{dn}(1-\lambda)^2-a_{dd}\right)}{\left(a_{nd}(1-\lambda)^2+a_{dd}\right)^3\left(a_{dn}(1-\lambda)^2+a_{dd}\right)(1-\lambda)}$$

$$-\frac{a_{nd}\left(1-1/p_{s_2}\right)^2}{\left(a_{nd}(1-\lambda)^2+a_{dd}\right)^4} *$$

$$*\left(4(a_{nd}+a_{dd})a_{nd}\lambda(1-2\lambda)+3a_{nd}^2\lambda^4+(a_{nd}+a_{dd})^2\right)$$

or, equivalently,

$$\partial^2 U_1(s_1,r_1^{UU},r_2^{UU},\lambda)\Big/\partial\lambda^2\Big|_{extremum}$$

$$=\frac{a_{nd}\left(1-1/p_{s_2}\right)^2}{\left(a_{nd}(1-\lambda)^2+a_{dd}\right)^4\left(a_{dn}(1-\lambda)^2+a_{dd}\right)(1-\lambda)} *$$

$$\Big(3a_{nd}^2a_{dn}\lambda^6-2a_{nd}\left(7a_{nd}a_{dn}-2a_{nd}a_{dd}+4a_{dn}a_{dd}\right)\lambda^5$$
$$-a_{nd}\left(-25a_{nd}a_{dn}+5a_{nd}a_{dd}-22a_{dn}a_{dd}\right)\lambda^4$$
$$-4\left(a_{nd}+a_{dd}\right)\left(5a_{nd}a_{dn}+2a_{nd}a_{dd}-a_{dn}a_{dd}\right)\lambda^3$$
$$+\left(a_{nd}+a_{dd}\right)\left(5a_{nd}a_{dn}+14a_{nd}a_{dd}-9a_{dn}a_{dd}\right)\lambda^2$$
$$+2\left(a_{nd}+a_{dd}\right)\left(a_{nd}a_{dn}-2a_{nd}a_{dd}+3a_{dn}a_{dd}\right)\lambda$$
$$-\left(a_{nd}+a_{dd}\right)^2\left(a_{dn}+a_{dd}\right)\Big).$$

As the expression

$$\frac{a_{nd}\left(1-1/p_{s_2}\right)^2}{\left(a_{nd}\left(1-\lambda\right)^2+a_{dd}\right)^4\left(a_{dn}\left(1-\lambda\right)^2+a_{dd}\right)\left(1-\lambda\right)}$$

is positive, the sign of the second derivative in the extremum is determined by the sign of

$$\begin{aligned}
&S\left(a_{nd}, a_{dn}, a_{dd}, \lambda\right) \equiv \\
&\Big(3a_{nd}^2 a_{dn}\lambda^6 - 2a_{nd}\left(7a_{nd}a_{dn} - 2a_{nd}a_{dd} + 4a_{dn}a_{dd}\right)\lambda^5 \\
&-a_{nd}\left(-25a_{nd}a_{dn} + 5a_{nd}a_{dd} - 22a_{dn}a_{dd}\right)\lambda^4 \\
&-4\left(a_{nd}+a_{dd}\right)\left(5a_{nd}a_{dn} + 2a_{nd}a_{dd} - a_{dn}a_{dd}\right)\lambda^3 \\
&+\left(a_{nd}+a_{dd}\right)\left(5a_{nd}a_{dn} + 14a_{nd}a_{dd} - 9a_{dn}a_{dd}\right)\lambda^2 \\
&+2\left(a_{nd}+a_{dd}\right)\left(a_{nd}a_{dn} - 2a_{nd}a_{dd} + 3a_{dn}a_{dd}\right)\lambda \\
&-\left(a_{nd}+a_{dd}\right)^2\left(a_{dn}+a_{dd}\right)\Big)
\end{aligned}$$

Therefore the sufficient condition for the local extremum λ^* to be a maximum is that

$$S\left(a_{nd}, a_{dn}, a_{dd}, \lambda\right) < 0 \tag{16}$$

for all $\lambda \in [0, 1]$. Note also that there could be only one maximum in this case as country 1's utility is increasing at $\lambda = 0$ and decreasing as $\lambda \to 1$, therefore to have two local maxima, one needs to have a local minimum inbetween. This requires that $S\left(a_{nd}, a_{dn}, a_{dd}, \lambda\right)$ is positive at that point, which contradicts our condition (16).

However, condition (16) is difficult to interpret. Let us demonstrate that if countries are symmetric in terms of default risks ($a_{dn} = a_{nd} \equiv a$), it will always hold.

$$\begin{aligned}
& S\left(a, a, a_{dd}, \lambda\right) \\
\equiv\; & 3a^3\lambda^6 - 2a^2\left(7a + 2a_{dd}\right)\lambda^5 + a^2\left(25a + 17a_{dd}\right)\lambda^4 \\
& -4a\left(a+a_{dd}\right)\left(5a+a_{dd}\right)\lambda^3 + 5a\left(a+a_{dd}\right)^2\lambda^2 \\
& +2a\left(a+a_{dd}\right)^2\lambda - \left(a+a_{dd}\right)^3 \\
=\; & \left(3a^2\lambda^4 - 4a\left(2a+a_{dd}\right)\lambda^3 + 6a\left(a+a_{dd}\right)\lambda^2 - \left(a+a_{dd}\right)^2\right) * \\
& * \left(a(1-\lambda)^2 + a_{dd}\right)
\end{aligned}$$

The first part of this product is always positive. Consider the second part of this product

$$\begin{aligned} s(a, a, a_{dd}, \lambda) &\equiv 3a^2\lambda^4 - 4a(2a + a_{dd})\lambda^3 \\ &\quad +6a(a + a_{dd})\lambda^2 - (a + a_{dd})^2 \end{aligned}$$

We see that the derivative of $s(a, a, a_{dd}, \lambda)$ with respect to λ is always positive so that $s(a, a, a_{dd}, \lambda)$ is increasing in λ over [0, 1]

$$s'(a, a, a_{dd}, \lambda) \equiv 12a\lambda(1 - \lambda)(a_{dd} + a(1 - \lambda)) > 0$$

$$\begin{aligned} s(a, a, a_{dd}, 0) &= -(a + a_{dd})^2 < 0 \\ s(a, a, a_{dd}, 1) &= -a_{dd}^2 < 0. \end{aligned}$$

Thus, $s(a, a, a_{dd}, \lambda)$ reaches its maximum at $\lambda = 1$ and it is negative there

$$s(a, a, a_{dd}, 1) = -a_{dd}^2 < 0.$$

That implies that $S(a, a, a_{dd}, \lambda) < 0$ for all $\lambda \in [0, 1]$, or, equivalently, that in the case where countries face symmetric risks, they always have a single best preferred redistribution rule.

Finally, since $S(a_{nd}, a_{dn}, a_{dd}, \lambda)$ is continuous in its arguments, the uniqueness of maximum is also ensured as long as the countries are not too asymmetric in terms of default risks (which holds for all our numerical examples).

It also needs to be mentioned that the asymmetry of risks is not sufficient to yield a non-concavity in λ for the utility function. Many constellations with very asymmetric risks will still produce a single-maximum utility outcome.

A.7. Proof that $\lambda > 0$ in Example 1

In a union of two completely identical countries the mutual insurance rule is given by equation

$$\lambda^{UU} = \frac{1}{2} - \frac{a_{nd}\left(\lambda^{UU}\right)^2(1 - \lambda^{UU})}{a_{nd}(1 - \lambda^{UU})^2 + a_{dd}}.$$

It can be rewritten as

$$\frac{(1 - \lambda^{UU})\left(3\lambda^{UU} - 1\right)}{(1 - 2\lambda^{UU})} = \frac{a_{dd}}{a_{nd}}.$$

The LHS of this equation changes monotonically increases from 0 to $+\infty$ when λ changes from $\frac{1}{3}$ to $\frac{1}{2}$. Therefore for any values of a_{dd} and a_{nd} there is a unique solution of this equation $\lambda^{UU} \in \left[\frac{1}{3}, \frac{1}{2}\right)$.

A.8. Proof of Result 2

Consider the equation that determines the interior solution for λ

$$\begin{aligned} \Phi &\equiv a_{dn}\left(1 - 1/p_{s_1}\right)^2 \frac{1-\lambda}{\left(a_{dn}(1-\lambda)^2 + a_{dd}\right)^2} \\ &\quad - a_{nd}\lambda\left(1 - 1/p_{s_2}\right)^2 \frac{a_{nd} - \lambda^2 a_{nd} + a_{dd}}{\left(a_{nd}(1-\lambda)^2 + a_{dd}\right)^3} \\ &= 0. \end{aligned} \tag{17}$$

Taking the full derivative with respect to λ and p_{s_i} implies that

$$\frac{d\lambda}{dp_{s_i}} = -\frac{\partial\Phi/\partial p_{s_i}}{\partial\Phi/\partial\lambda}.$$

As in the interior solution $\partial\Phi/\partial\lambda > 0$, the sign of $d\lambda/dp_{s_i}$ is equal to the sign of $\partial\Phi(\lambda)/\partial p_{s_i}$.

$$\frac{\partial\Phi}{\partial p_{s_1}} = 2a_{dn}\left(1 - 1/p_{s_1}\right)\frac{1-\lambda}{\left(a_{dn}(1-\lambda)^2 + a_{dd}\right)^2}\frac{1}{\left(p_{s_1}\right)^2} > 0$$

$$\frac{\partial\Phi}{\partial p_{s_2}} = -2a_{nd}\lambda\left(1 - 1/p_{s_2}\right)\frac{a_{nd} - \lambda^2 a_{nd} + a_{dd}}{\left(a_{nd}(1-\lambda)^2 + a_{dd}\right)^3}\frac{1}{\left(p_{s_2}\right)^2} < 0$$

which proves Result 2.

A.9. Proof of Result 3

Similarly to the proof of Result 2 (Appendix A.6.), the sign of the impact of each default probability on λ is equal to the sign of the partial derivative of Φ with respect to this default probability.

$$\frac{\partial\Phi}{\partial a_{dn}} = -\left(1 - 1/p_{s_1}\right)\frac{(1-\lambda)\left(a_{dn}(1-\lambda)^2 - a_{dd}\right)}{\left(a_{dn}(1-\lambda)^2 + a_{dd}\right)^3}$$

This derivative can have either sign depending on the relative size of a_{dn} and a_{dd} and optimal λ.

$$
\begin{aligned}
\frac{\partial \Phi}{\partial a_{nd}} &= \frac{-\lambda\left(1-1/p_{s_2}\right)^2}{\left(a_{nd}(1-\lambda)^2+a_{dd}\right)^4}\Big[a_{nd}^2\lambda^4-2a_{nd}^2\lambda^3-4a_{nd}a_{dd}\lambda^2 \\
&\quad +a_{nd}\left(2a_{dd}+a_{nd}\right)\lambda-a_{nd}^2+a_{dd}^2\Big]
\end{aligned}
$$

Again, the sign of this derivative is ambiguous.

Finally,

$$
\begin{aligned}
\frac{\partial \Phi}{\partial a_{dd}} &= -2\frac{a_{dn}\left(1-1/p_{s_1}\right)^2(1-\lambda)}{\left(a_{dn}(1-\lambda)^2+a_{dd}\right)^3} \\
&\quad +2a_{nd}\lambda\left(1-1/p_{s_2}\right)^2\frac{a_{nd}(-2\lambda^2+\lambda+1)+a_{dd}}{\left(a_{nd}(1-\lambda)^2+a_{dd}\right)^4}
\end{aligned}
$$

The first component of this sum is negative, while the second one is positive (as $-2\lambda^2+\lambda+1\geq 0$ for $\lambda\in[0,1]$). Therefore the overall sign of this derivative is ambiguous, which completes the proof.

A.10. Proof of Result 4

Own safe energy prices influence risky energy consumption both directly and through redistribution rule λ. However, as already mentioned in the text, each country's risky energy consumption is not affected directly by the other country's safe energy prices. Therefore, the impact of a change in the risky price of the other country comes only through a change in λ.

$$
\frac{dr_i^{UU}}{dp_{s_i}}=\frac{\partial r_i^{UU}}{\partial p_{s_i}}+\frac{dr_i^{UU}}{d\lambda}\frac{d\lambda}{dp_{s_i}}
$$

$$
\frac{dr_i^{UU}}{dp_{s_j}}=\frac{dr_i^{UU}}{d\lambda}\frac{d\lambda}{dp_{s_j}}\text{ for } j\neq i.
$$

We know from equations (5) and (6) that $\partial r_i^{UU}/\partial p_{s_i}>0$ and

$dr_i^{UU}/d\lambda > 0$. From this and Result 2 it follows that

$$\frac{dr_1^{UU}}{dp_{s_1}} > 0,$$
$$\frac{dr_2^{UU}}{dp_{s_1}} > 0,$$
$$\frac{dr_1^{UU}}{dp_{s_2}} < 0,$$

and the sign of dr_2^{UU}/dp_{s_2} is ambiguous as $\partial r_2^{UU}/\partial p_{s_2} > 0$ and $dr_2^{UU}/d\lambda * d\lambda/dp_{s_2} < 0$.

A.11. Proof of Result 5

Consider the effect of a change in the exogenous parameter b (where b can denote the safe energy price in either country p_{s_1}, p_{s2} or either of the default probabilities a_{nd}, a_{dn}, a_{dd}) on country 1's welfare.

$$\frac{dW_1}{db} = \frac{\partial W_1}{\partial b} + \frac{\partial W_1}{\partial \lambda}\frac{d\lambda}{db} + \frac{\partial W_1}{\partial r_1}\frac{\partial r_1}{\partial b} + \frac{\partial W_1}{\partial r_2}\frac{\partial r_2}{\partial b}.$$

(where the partial derivatives of r_i capture the effect of the exogenous parameters on W directly through r_i, while the effect through λ enters through $\partial W_1/\partial\lambda$). In the second stage country 1 optimally chooses its risky energy consumption. Therefore the envelope theorem ensures that $\partial W_1/\partial r_1 = 0$. Similarly, being a leading country in the union, country 1 chooses λ to maximize its own welfare, which, by envelope theorem, results in $\partial W_1/\partial\lambda = 0$. Therefore for any exogenous parameter b

$$\frac{dW_1}{db} = \frac{\partial W_1}{\partial b} + \frac{\partial W_1}{\partial r_2}\frac{\partial r_2}{\partial b}.$$

For example,

$$\frac{dW_1}{dp_{s_1}} = \frac{\partial W_1}{\partial p_{s_1}} + \frac{\partial W_1}{\partial r_2}\frac{\partial r_2}{\partial p_{s_1}} = \frac{\partial W_1}{\partial p_{s_1}},$$

as r_2 does not depend of p_{s_1} directly. Therefore

$$\frac{dW_1}{dp_{s_1}} = \frac{r_1}{p_{s_1}^2} > 0$$

Similarly,

$$\frac{dW_1}{dp_{s_2}} = \frac{\partial W_1}{\partial p_{s_2}} + \frac{\partial W_1}{\partial r_2}\frac{\partial r_2}{\partial p_{s_2}} = \frac{\partial W_1}{\partial r_2}\frac{\partial r_2}{\partial p_{s_2}}.$$

As $\partial r_2/\partial p_{s_2} > 0$ and

$$\frac{\partial W_1}{\partial r_2} = -a_{nd}\lambda^2 r_2 < 0$$

we conclude that

$$\frac{dW_1}{dp_{s_2}} < 0.$$

The effects of the default probabilities are calculated in a similar way:

$$\frac{dW_1}{da_{dn}} = \frac{\partial W_1}{\partial a_{dn}} + \frac{\partial W_1}{\partial r_2}\frac{\partial r_2}{\partial a_{dn}} = \frac{\partial W_1}{\partial a_{dn}} = -\frac{(1-\lambda)^2 r_1^2}{2} < 0$$

$$\begin{aligned}\frac{dW_1}{da_{nd}} &= \frac{\partial W_1}{\partial a_{nd}} + \frac{\partial W_1}{\partial r_2}\frac{\partial r_2}{\partial a_{nd}} = \frac{\partial W_1}{\partial a_{nd}} + \frac{\partial W_1}{\partial r_2}\frac{\partial r_2}{\partial a_{nd}} \\ &= -\frac{(\lambda r_2)^2}{2} + a_{nd}\lambda^2 r_2 \frac{\left(1 - 1/p_{s_2}\right)(1-\lambda)^2}{\left(a_{nd}(1-\lambda)^2 + a_{dd}\right)^2}.\end{aligned}$$

The first component of the sum is negative and the second positive, so that the overall effect is unclear.

$$\begin{aligned}\frac{dW_1}{da_{dd}} &= \frac{\partial W_1}{\partial a_{dd}} + \frac{\partial W_1}{\partial r_2}\frac{\partial r_2}{\partial a_{dd}} = \frac{\partial W_1}{\partial a_{dd}} + \frac{\partial W_1}{\partial r_2}\frac{\partial r_2}{\partial a_{dd}} \\ &= -\frac{(r_1)^2}{2} + a_{nd}\lambda^2 r_2 \frac{\left(1 - 1/p_{s_2}\right)}{\left(a_{nd}(1-\lambda)^2 + a_{dd}\right)^2}.\end{aligned}$$

Again, the overall effect is ambiguous.

Now let us turn to the welfare of the second country. The envelope theorem ensures that $\partial W_2/\partial r_2 = 0$ due to the efficient choice of r_2 in the second stage of the game. However, the impact of an exogenous parameter b through λ is now non-zero:

$$\frac{dW_2}{db} = \frac{\partial W_2}{\partial b} + \frac{\partial W_2}{\partial r_1}\frac{\partial r_1}{\partial b} + \frac{\partial W_2}{\partial \lambda}\frac{d\lambda}{db}.$$

The implications of having this additional component ($\frac{\partial W_2}{\partial \lambda}\frac{d\lambda}{db}$) in the expression for the derivative are discussed in the main text.

A.12. Risky energy demand in a coordinated union (equations (10) and (11))

The maximization problem of the social planner in the second stage is given by

$$\begin{aligned}
&\max_{r_1,r_2} U_1(r_1, r_2,\lambda) + U_2(r_2, r_1,\lambda)\\
= &\max_{r_1,r_2} \left\{ s_1 + r_1 - \frac{\left[a_{nd}\,(\lambda r_2)^2 + a_{dn}\,((1-\lambda)r_1)^2 + a_{dd}(r_1)^2\right]}{2}\right.\\
&\left. + s_2 + r_2 - \frac{\left[a_{nd}\,((1-\lambda)r_2)^2 + a_{dn}\,(\lambda r_1)^2 + a_{dd}(r_2)^2\right]}{2}\right\}\\
&s.t.\ p_{s_i}s_i + r_i \leq B_i,\ \ i = 1, 2.
\end{aligned}$$

The first order conditions with respect to the risky consumption of each country are

$$-\frac{1}{p_{s_1}} + 1 - \left(a_{dn}(1-\lambda)^2 + a_{dn}\,(\lambda)^2 + a_{dd}\right) r_1 = 0$$

$$-\frac{1}{p_{s_2}} + 1 - \left(a_{nd}(1-\lambda)^2 + a_{dn}\,(\lambda)^2 + a_{dd}\right) r_2 = 0$$

which yields equations (10) and (11).

A.13. Proof that $\lambda^{CU} = 1/2$

At the first stage the social planner of a coordinated union chooses λ taking into account the choice at the second stage. As the second-stage decisions are made efficiently, the envelope theorem ensures that

$$\frac{\partial\left[U_1(r_1, r_2,\lambda) + U_2(r_2, r_1,\lambda)\right]}{\partial r_i} = 0.$$

Therefore the first order conditions for the choice of redistribution rule λ is

$$-a_{nd}r_2^2\lambda + a_{dn}(1-\lambda)r_1^2 + a_{nd}(1-\lambda)r_2^2 - a_{dn}\lambda r_1^2 = 0$$

which can be rewritten as

$$\lambda = \frac{a_{dn}r_1^2 + a_{nd}r_2^2}{2\left(a_{dn}r_1^2 + a_{nd}r_2^2\right)} = \frac{1}{2}.$$

A.14. Proof of Result 6

The fact that $\lambda^{CU} = 1/2$ allows to rewrite the welfare of the first country as

$$\begin{aligned} W_1^{CU} &= \frac{B - r_1^{CU}}{p_{s_1}} + r_1 \\ &- \frac{a_{nd}\left(\frac{1}{2}r_2^{CU}\right)^2 + a_{dn}\left(\frac{1}{2}r_1^{CU}\right)^2 + a_{dd}(r_1^{CU})^2}{2} \end{aligned} \tag{18}$$

where

$$\begin{aligned} r_1^{CU}(\lambda) &= \frac{1 - 1/p_{s_1}}{a_{dn}/2 + a_{dd}}, \\ r_2^{CU}(\lambda) &= \frac{1 - 1/p_{s_2}}{a_{nd}/2 + a_{dd}}. \end{aligned}$$

Substituting the risky energy demand in an UU into the formula (18) and taking the derivatives thus yields the effect of prices on the welfare of country 1

$$\frac{dW_1^{CU}}{dp_{s_1}} = -\frac{1}{p_{s_1}^2}\left(B - r_1^{CU}\frac{(3a_{dn} + 4a_{dd})}{2\left(a_{dn} + 2a_{dd}\right)}\right) <> 0;$$

$$\frac{dW_1^{CU}}{dp_{s_2}} = -\frac{\left(1 - 1/p_{s_2}\right)a_{nd}}{p_{s_2}^2\left(a_{nd} + 2a_{dd}\right)^2} < 0.$$

Similarly, the effect of default probabilities is given by the following expressions: The effect of the local probability of default is negative

$$\frac{dW_1^{CU}}{da_{dn}} = -\frac{\left(1 - 1/p_{s_1}\right)^2(3a_{dn} + 2a_{dd})}{2\left(a_{dn} + 2a_{dd}\right)^3} < 0;$$

The effect of the foreign probability of default may be positive or negative depending on the relation between a_{nd} and a_{dd}

$$\frac{dW_1^{CU}}{da_{dn}} = -\frac{\left(1 - 1/p_{s_1}\right)^2 (a_{nd} - 2a_{dd})}{(a_{nd} + 2a_{dd})^3} <> 0$$

and finally, the effect of the double default probability is ambiguous as well

$$\begin{aligned}\frac{dW_1^{CU}}{da_{dd}} &= -4\left(1 - 1/p_{s_1}\right)^2 \frac{(a_{dn} + a_{dd})}{(a_{dn} + 2a_{dd})^3} \\ &\quad +2\left(1 - 1/p_{s_2}\right)^2 \frac{a_{nd}}{(a_{nd} + 2a_{dd})^3} \quad < \ > 0\end{aligned}$$

since the first component of the sum is negative and the second is positive. The results for the second country are completely symmetric.

A.15. Proof of Result 8

If the countries are exactly symmetric in terms of default probabilities ($a_{nd} = a_{dn}$), the equation (17) that determines the choice of λ by country 1 in an UU takes form

$$\begin{aligned}&\left(1 - \frac{1}{p_{s_1}}\right)^2 \left(1 - \lambda^{UU}\right) - \\ &\lambda^{UU}\left(1 - \frac{1}{p_{s_2}}\right)^2 \frac{a_{nd}\left(1 - \left(\lambda^{UU}\right)^2\right) + a_{dd}}{\left(a_{nd}(1 - \lambda^{UU})^2 + a_{dd}\right)} = 0\end{aligned}$$

Denote by K the function of relative prices of safe energies in two countries

$$K = \frac{\left(1 - 1/p_{s_1}\right)^2}{\left(1 - 1/p_{s_2}\right)^2},$$

$K < 1$ because the price of safe energy in country 1 is lower than the price of safe energy in country 2. Then the equation (17) can be further rewritten as

$$\Phi(\lambda^{UU}, K) = K\left(1-\lambda^{UU}\right) - \lambda^{UU}\frac{a_{nd}\left(1-\left(\lambda^{UU}\right)^2\right)+a_{dd}}{\left(a_{nd}(1-\lambda^{UU})^2+a_{dd}\right)} = 0. \quad (19)$$

Fix the set of default probabilities (a_{nd}, a_{dn}, and a_{dd}). Then the redistribution rule λ^{UU} increases in K as

$$\frac{d\lambda}{dK} = -\frac{\partial\Phi/\partial K}{\partial\Phi/\partial\lambda}$$

and $\partial\Phi/\partial\lambda < 0$ in interior maximum, while

$$\partial\Phi/\partial K = \left(1-\lambda^{UU}\right) > 0.$$

If countries are symmetric in terms of default probabilities, the risky energy consumption in CU exceeds the one is UU iff

$$r_i^{CU} = \frac{1-1/p_{s_i}}{a_{dn}/2+a_{dd}} > \frac{1-1/p_{s_i}}{a_{dn}(1-\lambda^{UU})^2+a_{dd}} = r_i^{UU} \quad (20)$$

which is equivalent to

$$\lambda^{UU} < 1-\sqrt{1/2}.$$

As we have shown that redistribution rule λ^{UU} increases in K, given set of the default probabilities, there should be a threshold $\overline{K}$ such that $\lambda^{UU} < 1-\sqrt{1/2}$ if and only if $K < \overline{K}$. In other words for relation (20) to hold, K should belong to $\left(0, \overline{K}\right)$, where $\overline{K}$ is defined by substituting $\lambda^{UU} = 1-\sqrt{1/2}$ into the equation (19)

$$\overline{K}\sqrt{1/2} - \left(1-\sqrt{1/2}\right)\frac{a_{nd}\left(\sqrt{2}-\frac{1}{2}\right)+a_{dd}}{(a_{nd}/2+a_{dd})} = 0$$

or equivalently

$$\overline{K} = \left(\sqrt{2}-1\right)\frac{a_{nd}\left(\sqrt{2}-\frac{1}{2}\right)+a_{dd}}{(a_{nd}/2+a_{dd})}. \quad (21)$$

Clearly, $\overline{K} > 0$, so the set of prices ensuring that the risky energy consumption in an UU is below the one of a CU for both country members is non-empty. This proves the first part of the Result 8.

Moreover, equation (21) can also be rewritten as

$$\overline{K} = \left(\sqrt{2} - 1\right) \frac{\left(\sqrt{2} - \frac{1}{2}\right) a_{nd}/a_{dd} + 1}{1/2\,(a_{nd}/a_{dd}) + 1}$$

which implies that

$$\frac{d\overline{K}}{d\,(a_{nd}/a_{dd})} = 4\frac{\sqrt{2} - 1}{(a_{nd}/a_{dd} + 2)^2} > 0.$$

Namely, higher values of the ratio of the probability of a local default to the probability of double default a_{nd}/a_{dd} lower the threshold $\overline{K}$, which for the same p_{s_1} corresponds to a higher p_{s_2}. This completes the proof of Result 8.

Part VI

SVENSK SAMMANFATTNING

I grönboken av den 8 mars 2006, "En europeisk strategi för en hållbar, konkurrenskraftig och trygg energiförsörjning", formulerar den Europeiska Kommissionen tre huvudprinciper för en gemensam europeisk energipolitik: 1) konkurrenskraft, för att trygga rimliga energipriser, 2) försörjningstrygghet, för att säkerställa energitillförseln och 3) hållbarhet, för att ta miljöhänsyn.

En av dessa principer, försörjningstrygghet eller energisäkerhet, har ådragit sig särskild uppmärksamhet under de senaste åren. EU importerar över hälften av sin energikonsumtion och en växande efterfrågan innebär att importberoendet kommer att öka ytterligare. En stor del av energiimporten härstammar från politiskt instabila regioner och från ett fåtal leverantörer, vilket är förenat med stora politiska och ekonomiska risker. De senaste årens energikriser orsakade av rysk-ukrainska och rysk-vitryska konflikter har ytterligare understrukit vikten av att öka energisäkerheten inom EU.

Ett flertal strategier för att trygga energiförsörjningen har förts fram i den europeiska debatten. Vissa åtgärder fokuserar på efterfrågesidan, andra reglerar energiutbudet och ytterligare förslag fokuserar på förbindelserna mellan medlemsstaterna och energileverantörerna. Dessa strategier för en gemensam energipolitik är väldiskuterade och har grundligt analyserats i en mängd studier. Huvuddelen av studierna tycks dock analysera försörjningstrygghet från ett säkerhetspolitiskt perspektiv eller fokusera på den inre energimarknadens funktionssätt. I den här studien demonstrerar vi hur en gemensam energipolitik kan ge upphov till snedvridande ekonomiska incitament och därigenom skapa så kallade ”moral hazard”-problem.[25] Denna ”moral hazard”-mekanism är välkänd

[25]”Moral hazard” är ett väletablerat engelsk begrepp inom nationalekonomi som hittills saknar svensk översättning. ”Moral hazard” uppstår för att en försäkrad individ eller institution inte själv drabbas fullt ut av de negativa effekterna av sitt handlande och därför har en tendens eller ett incitament att handla mindre försiktig än annars.

inom den ekonomiska litteraturen, men har sällan diskuterats inom ramen för energipolitik. Oss veterligen är denna studie den första som gör en formell analys av ”moral hazard” i relation till en europeisk energipolitik.

Angreppssätt. Analysen fokuserar på extern energisäkerhet, det vill säga på energiimport från leverantörer utanför EU. Vidare koncentrerar vi oss på en särskild aspekt av den europeiska energipolitiken, nämligen principen om ömsesidig försäkring, av den Europeiska Kommissionen även refererad till som solidaritet bland medlemsstaterna. En vanlig uppfattning är att denna solidaritetsmekanism kommer att främja en trygg energiförsörjning. Medlemsstaterna kompenserar varandra vid leveransavbrott, vilket tryggar en jämn energikonsumtion varvid välfärden ökar. Emellertid kan en gemensam energipolitik som innefattar ömsesidig försäkring vid bristsituationer leda till problem med ”moral hazard”. Försäkringsmekanismen innebär att medlemsstaterna inte själva bär de kostnader som den egna konsumtionen av riskfylld energi ger upphov till. Detta kan ge medlemsstaterna incitament att öka konsumtionen av riskfylld energi, vilket i sin tur ökar unionens exponering för risk.

Syfte. Syftet med den här Siepsrapporten är att analysera nyttan av en gemensam energipolitik och de potentiella kostnader som en solidarisk försäkringsmekanism kan ge upphov till. Rapportens två viktigaste bidrag är (i) ett index som uppskattar graden av risk förenad med extern energisäkerhet, dels för varje medlemsstat och dels för fyra sorters energislag (gas, olja, elektricitet och kol), (ii) en formell analys av de ”moral hazard”-problem som kan uppstå i samband med en europeisk energipolitik som innefattar en solidarisk försäkringsmekanism.

Disposition. Rapporten består av två delar. Den första delen diskuterar europeisk försörjningstrygghet medan den andra delen presenterar en formell analys av kostnader och nytta av en gemensam energipolitik, särskilt med avseende på en solidaritetsmekanism. De två första kapitlen ger en överblick av den europeiska energisäkerhetsproblematiken: kapitel ett definierar viktiga begrepp relaterade till energisäkerhet och kapitel två presenterar en översikt av den europeiska debatten om försörjningstrygghet och redogör för möjliga strategier att hantera försörjningskriser.

Kapitel tre presenterar ett index som skattar graden av risk förenad med energiimport. Detta index är konstruerat för att komma åt den kortsiktiga risken. Det som gör vår metod speciell är att vi presenterar ett separat index för varje energislag och rangordnar de europeiska länderna i enlighet med respektive index. Vårt index kombinerar nettoimportberoende med en proxy för den politiska risken i det exporterande landet och den uppmätta distansen mellan det konsumerande landet och de exporterande länderna. Genom att använda IEA-data från 2006, har vi konstruerat index för arton europeiska länder och för tre konventionella energislag: olja, gas och kol. De flesta andra studier föreslår aggregerade energisäkerhetsindex som kombinerar olika energislag. Ett aggregerat index riskerar dock att vara vilseledande, i synnerhet med avseende på kortsiktig risk. Det kan visa sig vara en kostbar förenkling att förlita sig till ett aggregerat riskindex utan att ta hänsyn till energimix eftersom det inte är möjligt att substituera olika energislag på kort sikt. Polen uppvisar till exempel ett högt indexvärde för oljeförsörjning och ett relativt lågt index för gasförsörjning, medan situationen är omvänd för Portugal. Det är alltså en större risk för försörjningsavbrott av olja i Polen än i Portugal medan motsatsen gäller i fråga om försörjningsavbrott av gas. Med detta index har vi möjlighet att uppskatta den potentiella skadan orsakad av försörjningsavbrott på en specifik energimarknad i ett givet land. Detta skulle inte vara möjligt med ett aggregerat index som approximerar den genomsnittliga risken för försörjningsavbrott.

Rapportens andra del utgörs av en formell analys av de ”moral hazard” problem som kan uppstå i samband med en europeisk energipolitik som baseras på en solidaritetsprincip med ömsesidig försäkring. Vi ger såväl en icke-teknisk sammanfattning (kapitel fyra) som en rigorös analys (kapitel fem) av modellen. Vårt modellramverk låter oss relatera graden av ”moral hazard” med graden av politisk koordinering inom energisamarbetet samt studera hur ”moral hazard” påverkar energikonsumtionen och graden av solidaritet bland medlemsstaterna. Mer specifikt kan modellen beskrivas på följande sätt: Vi analyserar de ekonomiska beslut som fattas i de länder som kan konsumera dyr energi från säkra (utan risk för leveransavbrott) leverantörer eller billig energi från riskfyllda (med risk för leveransavbrott) leverantörer. Länderna kan antingen agera i autarki eller bilda en union. Om de bildar en union är de bundna till en gemensam energipolitik genom en överenskommelse om ömsesidig försäkring. Med andra ord kan länderna, åtminstone delvis, försäkra varandra mot leveransavbrott genom att överföra energi från ett icke-drabbat till ett drabbat partnerland. Tre typer av system behandlas. I *autarki* finns ingen ömsesidig försäkringsmekanism och länderna fattar beslut oberoende av varandra. I en *koordinerad union* strävar unionen efter att maximera den totala välfärden genom att samordna beslutsfattandet, både beträffande konsumtion av riskfylld energi och beträffande den solidariska försäkringens täckningsgrad. Även i en *okoordinerad union* försäkrar medlemsländerna varandra mot leveransavbrott. Emellertid bestämmer varje land sin energikonsumtion oberoende av varandra och ingen hänsyn tas till de negativa effekter denna kan ge upphov till för övriga medlemsländer. Genom att formalisera analysen på detta sätt är det möjligt att jämföra konsumtionsnivån av riskfylld energi, den solidariska försäkringens täckningsgrad samt välfärdseffekter under tre olika energipolitiska system. Kostnads-nyttoanalysen är beroende av vilken typ av koordination mellan medlemsländerna, graden av symmetri (med avseende på riskexponering och energipriser) mellan länderna, vilket land som sätter agendan samt möjligheten att få till stånd kompenserande transfereringar mellan länderna.

Resultaten visar att om länderna är perfekt koordinerade uppstår inte problemen med ”moral hazard”. Därför är en perfekt koordinerad union överlägsen autarki på grund av den ömsesidiga försäkringen. Emellertid beror varje enskilt lands vinning på graden av asymmetri i unionen. Om länderna är identiska vinner bägge på att bilda en union, men om asymmetrin är tillräckligt stor riskerar ett av länderna att hamna i ett sämre läge än under autarki. Anledningen är att det är kostsamt att tillhandahålla ömsesidig försäkring; ju högre risk för försörjningsavbrott hos övriga partnerländer desto högre kostnader för varje enskilt land. När länderna möter olika hög risk för leveransavbrott, kan solidarisk försäkring bli ytterst kostsam. En union kommer enbart att existera om det utbetalas kompenserande transfereringar från vinnarna till förlorarna, eller om ytterligare fördelar är förbundna med ett unionsmedlemsskap.

I en okoordinerad union skapar försäkringssituationen incitament att handla med mindre försiktighet (s.k. ”free-riding”) och överkonsumera riskfylld energi. Ett medlemsland som har ett stort inflytande över energipolitiken och kan sätta agendan försöker att minska sin ökade riskexponering genom att korrigera försäkringens täckningsgrad. Detta förstärker ineffektiviteten hos ett okoordinerat energipolitiskt samarbete men minskar samtidigt konsumtionen av riskfylld energi. Huruvida alla unionsmedlemmar vinner i en okoordinerad union beror åter igen på ländernas grad av asymmetri, men om kompenserande transfereringar utbetalas är en okoordinerad union överlägsen autarki. Emellertid ger en koordinerad union alltid högst välfärd.

Givet dessa resultat, avhandlar vi problematiken kring uppkomsten av en energipolitisk union, i synnerhet de incitament som finns för ett land att ingå i ett samarbete trots att det är kostsamt att delta. Vi diskuterar de fördelar som kan tänkas vara förenade med ett unionsmedlemsskap och de kostnader som är förbundna med att stå utanför. Vi diskuterar även sambanden mellan maktfördelningen inom unionen och samarbetets stabilitet och utfall.

Sammanfattning av resultaten och policyimplikationer. Ett antal slutsatser kan dras från rapportens huvudresultat.

1. Rapporten föreslår en uppsättning nya index som mäter risken förbunden med extern energiförsörjning för tre olika energislag (gas, olja och kol). Indexen visar att riskexponeringen och riskrangordning bland EU:s medlemsstater skiljer sig för olika energislag. Detta innebär att en metod som baseras på riskvärdering av skilda energislag, dvs. ett sektorialt angreppssätt, skulle bidra till en tillförlitligare skattning av de kortsiktiga externa energiriskerna. Eftersom

medlemsstaternas energirisk varierar för olika energislag, kan en tryggad energiförsörjning kräva olika policyinstrument för varje energislag, vilket endast kan bedömas utifrån ett sektorialt angreppssätt.

2. Välfärdsanalysen visar att det uppstår problem med ”free-riding”, dvs. att medlemsländer inte bär de egna kostnaderna utan åker snålskjuts på övriga medlemmar, när medlemmarnas ekonomiska beslut inte är perfekt koordinerade. Detta kan visa sig vara mycket kostsamt för medlemsländerna. Slutsatsen blir att det är nödvändigt att inrätta en stark central energimyndighet för att lösa de ”moral hazard” problem som kan uppstå i samband med en gemensam energipolitik som bygger på solidaritet mellan medlemsstater.

3. Analysen visar att graden av riskexponering inte alltid är korrelerad till effektivitet. Även utan ”moral hazard”-effekter kan medlemsländerna komma att konsumera en hög andel riskfylld energi under en central energimyndighet som driver en samordnad energipolik. En okoordinerad union med ojämn maktfördelning kan däremot ge upphov till en låg konsumtion av riskfylld energi. Om exempelvis det ledande landet är exponerat för en lägre grad av risk än övriga medlemsländer, kan det välja en låg försäkringsgrad för att minimera kostnaderna för ”moral hazard”-effekterna. Detta i sin tur minskar konsumtionen av riskfylld energi i alla medlemsländer. Emellertid är en sådan låg nivå ineffektiv eftersom länderna konsumerar en alltför stor andel säker, men dyr, energi och innehar en alltför låg försäkringstäckning. Detta betyder att försiktighet bör iakttas när konsumtionsnivån av riskfylld energi används som mått på försörjningstryggheten, vilket ofta har varit fallet i den europeiska debatten. Medan tillförlitlighetsgraden är större vid en jämförelse av olika länder vid en given tidpunkt, reflekteras inte enbart riskexponeringsgraden utan även de institutionella förändringarna i unionen i ett längre perspektiv. Därför bör

   (i) institutionella förändringar inom unionen snarare än rent kvantitativa mått beaktas, när energiförsörjningstryggheten ska estimeras, särskilt för att få ett långsiktigt perspektiv;

(ii) en gemensam energipolitik med syfte att trygga energiförsörjningen inte nödvändigtvis fordra en lägre konsumtionsnivå av riskfylld energi så länge energisamarbetet innebär en utökad koordination mellan medlemsländerna.

4. Vi hävdar slutligen att när vissa medlemsländer har större inflytande över energipolitiken än andra medlemmar skiftar nyttan med en ömsesidig försäkring mot den mer inflytelserika gruppen. Ett sätt att uppnå en rättvisare fördelning av vinsterna inom energisamarbetet kan vara att ha en uppsättning separata överenskommelser för varje energipolitisk fråga. Under dessa förhållanden skulle de mindre inflytelserika medlemsländerna välja att enbart delta i de energisamarbeten som gynnar dem, vilket skulle begränsa de agendasättande ländernas makt. Emellertid skulle det vara bättre att integrera de energipolitiska frågorna och samtidigt tillförsäkra en jämnare maktfördelning med avseende på energipolitiken bland medlemsländerna. Detta skulle gynna EU, både genom effektivare utfall och genom att förbättra energisamarbetets stabilitet. Försök att missbruka maktpositioner skulle förhindras av risken för vedergällning i övriga energifrågor och därigenom leda till ett mer samordnat agerande. Följaktligen är det troligt att en integrerad energipolitisk union med jämlik maktdelning är överlägsen en uppsättning separata överenskommelser för varje energipolitisk fråga.

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