MEASURING LONG-TERM ENERGY SUPPLY RISKS: A G7 RANKING

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ABSTRACT

The security of energy supply has again become a similarly hot topic as it was during the oil crises in the 1970s, not least due to the recent historical oil price peaks. In this paper, we analyze the energy security situation of the G7 countries using a statistical risk indicator and empirical energy data for the years 1978 through 2010. We find that Germany's energy supply risk has risen substantially since the oil price crises of the 1970s, whereas France has managed to reduce its risk dramatically, most notably through the deployment of nuclear power plants. As a result of the nuclear phase-out decision of 2011, Germany's supply risk can be expected to rise further and to approach the level of Italy. Due to its resource poverty, Italy has by far the highest energy supply risk among G7 countries.

JEL classification: C43, Q41.

KEYWORDS
Energy supply risk indicator, Herfindahl index.

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1. Introduction

The confluence of continuing instability in the Middle East, a growing resource nationalism, and a surge of oil demand by emerging countries, particularly China, has made energy supply security a high policy priority in the European Union (COM 2008a). Along with the almost ever-increasing significance of this topic, there is a growing number of contributions to the literature that have developed and employed quantitative security measures, with Sovacool et al. (2011), Lefèvre (2010, 2007), Löschel et al. (2010), Sovacool and Brown (2010), Vivoda (2010), Frondel and Schmidt (2009), Constantini et al. (2007), Kemmler and Spreng (2007), Scheepers et al. (2006, 2007), and Jansen et al. (2004) being among the most recent studies.

To empirically analyze both the past and future energy security situation of G7 countries, this article applies the statistical indicator of the long-term primary energy supply risk conceived by Frondel and Schmidt (2009). With this example, we will demonstrate that this indicator is both useful and meaningful: The inter-temporal picture drawn on the basis of our risk calculations appears to be perfectly in line with our qualitative risk analysis of these countries' past primary energy supply mixes.

In essence, the employed risk indicator condenses empirical information on the imports of fossil fuels, such as oil, gas, and coal, originating from a multitude of export countries, as well as data on the indigenous contribution to the domestic supply of all kinds of energy sources, including biofuels and other renewable energies. The empirical outcome is a single figure that characterizes the long-term total risk of a country's reliance on fossil fuel imports at a given point in time. While taking account of all energy sources used in a country, both renewable and non-renewable, the basic ingredients of the risk indicator are: (1) a country's own contribution to the total domestic supply of any fuel vis-a-vis the fuels' import shares, (2) proxies for the probabilities of supply disruptions in export countries, and (3) the diversification of the primary energy mix, that is, the variety of energy sources and technologies employed to satisfy demand.

Given the multitude of facets underpinning the notion of energy security, including physical, economic, social and environmental dimensions (see Sovacool, 2010), it appears to be hardly possible to integrate all of these aspects into a single indicator. The present approach, for example, ignores both resource prices and their volatility, as well as demand reductions, which are postulated by Jansen and Seebregts (2010:1655) to be most effective towards achieving a more secure energy economy. Rather, the concept employed here follows conventional tacks that take the demand for energy as exogenously given, thereby focusing on the supply side of primary energy sources. Our aim is to illustrate how the conceived measure of energy security can serve as an indicator of physical availability or vulnerability based on a comparative analysis of the G7 countries.

In the terminology of Löschel et al. (2010), who distinguish between ex-post and ex-ante indicators, Frondel and Schmidt's (2009) concept should be regarded as an ex-ante indicator that basically addresses the issue of whether one may expect major welfare losses due to potential frictions in a country's energy markets. It is therefore to be emphasized that the concept employed in our article gauges the *potential* long-term supply risk as contrasted by the actual supply risk. While the potential supply risk captures the notion of subjective or perceived energy security, the actual supply risk is, along the lines of the efficient market hypothesis (Fama, 1970), best indicated in functioning energy markets by market price signals. This distinction can give rise to a circumstance in which the actual supply risk had not changed at all over some interval in the past, even when Frondel and Schmidt's (2009) indicator points to a drastic increase in the potential supply risk over that interval. Such a case would show that these authors' concept is not an appropriate ex-post indicator, which according to Löschel et al. (2010:1668) should attempt to answer the question of whether the energy markets caused a major friction to the economy in the past.

The following section provides for a concise summary of the empirical concept that Frondel and Schmidt (2009) suggest for measuring a country's long-term energy supply risk. In Section 3, this concept is applied to empirical data of the G7 Countries provided by the International Energy Agency (IEA) for the years 1978-2010, as well as to projections for 2020, followed by an in-depth analysis to provide for a qualitative explanation of the outcomes of our risk calculations. The last section summarizes and concludes.

2. AN EMPIRICAL SUPPLY RISK MEASURE

While there are several competing concepts, Frondel and Schmidt's (2009) build on the inspiring work of Jansen et al. (2004) in that their risk indicator strongly relies on the notion of diversity. Yet, in contrast to Jansen et al. (2004), who base their energy security indicator on Shannon's (1948) diversity measure, the risk indicator's fundamental basis is Herfindahl's (1950) concentration index. This choice is due to Frondel and Schmidt's scepticism concerning whether any meaningful security indicator may be based on Shannon's diversity measure.

Denoting the probability of supply disruptions in export country *j* by r_j, Frondel and Schmidt (2009) suggest the following quadratic form as a measure capturing a nation's supply risk related to fuel *f*:

$$\text{risk}_f := \mathbf{x}_f^T \boldsymbol{R}\, \mathbf{x}_f = x_{fd}^2\ r_d + \sum_{j=1}^{J} x_{fj}^2\ r_j, \tag{1}$$

where the share of export country *j* in the domestic supply of energy resource *f* is designated by x_{fj}, and the respective indigenous contribution by x_{fd}. By definition,

$$x_{fd} + x_{f1} + \cdots + x_{fj} + \cdots + x_{fJ} = 1, \quad f = 1, \ldots, F. \tag{2}$$

Matrix $\boldsymbol{R}$, which can be designated as risk matrix, is diagonal. Its diagonal elements are given by vector $\boldsymbol{r}^T := (r_d, r_1, \ldots, r_j, \ldots, r_J)$, which may be denoted as risk vector. Arguably, the risk of a long-term disruption of a nation's own contribution to domestic supply can be assumed to equal zero: $r_d = 0,$ notwithstanding potential transient short-term supply disruptions. It bears noting that this specific setting is inconsequential. In fact, by refraining from this specific setting, instead allowing that r_d lies somewhere in the interval [0;1], the import country may be treated in the same way as any other fuel-providing export country.

From the perspective of an import country, the components of share vector $\boldsymbol{x}_f$ defined by $\boldsymbol{x}_f^T := (x_{fd}, x_{f1}, \dots, x_{fj}, \dots, x_{fJ})$ are the primary instruments to improve supply security. If x_{fd} equals unity, a nation is autarkic with respect to fuel *f*. In this polar case, the supply risk related to fuel *f*, as defined by (1), takes on the minimum value of zero, indicating a perfectly secure long term fuel supply. In the opposite polar case, in which the total supply of fuel *f* exclusively originates from a highly instable export country such that $r_j = 1$, risk_f takes on the maximum value of unity. In short, the fuel-specific risk defined by (1) is normalized: $0 \leq \text{risk}_f \leq 1$.

Definition (1) comprises three major aspects of energy security: (1) a country's own contribution x_{fd} to the total domestic supply of fuel *f*, (2) the political and economic stability of export countries as captured by risk vector $\boldsymbol{r}$, and (3) the diversification of imports as reflected by vector $\mathbf{x}_f$. The role of diversification is incorporated in the fuel-specific indicator risk_f by building on Herfindahl's (1950) index, with which one can measure the concentration of fuel imports:

$$\boldsymbol{H}_f := s_{f1}^2 + \cdots + s_{fj}^2 + \cdots + s_{fJ}^2, \tag{3}$$

where s_{fj} denotes the share of export country *j* in total imports of fuel *f*. The share s_{fj} relates to country *j's* contribution x_{fj} to the total domestic supply of fuel *f* as follows:

$$x_{fj} = s_{fj}\,(1 - x_{fd}). \tag{4}$$

According to this expression, increasing the indigenous contribution x_{fd} decreases x_{fj}, thereby alleviating the import dependency with respect to fuel *f* and, hence, reducing risk_f.

To measure a nation's entire vulnerability with respect to all kinds of fuels and energy sources, Frondel and Schmidt (2009) suggest evaluating the following generalization of the fuel-specific supply risk defined by expression (1):

$$\text{risk} := \boldsymbol{w}^T \boldsymbol{X}^T \boldsymbol{R}\ \mathbf{X}\,\mathbf{w} = \boldsymbol{w}^T \boldsymbol{\pi}\, \boldsymbol{w}. \tag{5}$$

$\mathbf{w}^T := (w_1, \dots, w_f, \dots, w_F)$ represents a vector whose non-negative components w_f reflect the shares of the various fuels and energy sources in a nation's total energy consumption and, hence, add to unity: $w_1 + \cdots + w_F = 1$. The columns of matrix $\boldsymbol{X}$ comprise the indigenous as well as the export country's contributions to the domestic supply of each of the *F* fuels and energy sources:

$$\boldsymbol{X} := \begin{pmatrix} x_{1d} & . & x_{fd} & . & x_{Fd} \\ x_{11} & . & x_{f1} & . & x_{F1} \\ . & . & . & . & . \\ x_{1j} & . & x_{fj} & . & x_{Fj} \\ . & . & . & . & . \\ x_{1J} & . & x_{fJ} & . & x_{FJ} \end{pmatrix}. \tag{6}$$

The diagonal elements π_{ff} of the product matrix $\boldsymbol{\pi} = \boldsymbol{X}^T \boldsymbol{R}\, \boldsymbol{X}$ are identical to the fuel-specific supply risks: $\pi_{ff} = \text{risk}_f = \sum_j^J x_{fj}^2\, r_j \geq 0$. Non-vanishing off-diagonal elements, $\pi_{f_1 f_2} = \sum_j^J x_{f_1 j}\, x_{f_2 j} r_j > 0$, where $f_1, f_2 = 1, \dots F,\ f_1 \neq f_2$, take account of the fact that, for instance, oil supply disruptions in an export country may be correlated with those of gas. Finally, it bears noting that the total supply risk (5) is normalized and, hence, its values fall between zero and unity. In practice, though, this indicator's concrete outcome is typically much smaller than unity.

Before employing these concepts to empirical data, it deserves noting that, of course, any selection of a diversification indicator, such as Shannon's diversity measure or Herfindahl's concentration index, bears its specific, as well as common, problems, such as the dependence of its values on the partitioning of options (Stirling, 2010:156). In our example, partitioning of options refers to either the diversity of export countries or the variety of energy sources and technologies employed to satisfy demand. With respect to the latter aspect, the question arises at what scale of contributions is a niche technology, such as photovoltaics, considered to add to the diversity of the energy system (Stirling, 2010:158).

Whether renewable technologies are split up into a multitude of diverse technologies with so far rather small contributions to the energy mix or are combined to a single category is irrelevant for risk indicator (5), however, as long as we treat renewables like a domestic fuel, that is, attribute no risk to these technologies – a treatment that is clearly contentious, but seems to be appropriate for our long-term perspective, in which renewables diminish the import of fossil fuels. Furthermore, basing risk indicator (5) on Herfindahl's concentration index makes it quite robust with respect to either aggregating or separating fuel imports from a range of export countries with small contributions to the domestic energy demand. This is due to the fact that the share x_{fj} of export country *j* in the domestic supply of energy resource *f* is squared in both the Herfindahl index and risk indicator (1), thereby under-weighing the importance of such export countries in our evaluation of the energy supply risks of G7 countries.

3. ENERGY SUPPLY RISKS OF G7 COUNTRIES

On the basis of primary energy data provided by the International Energy Agency (IEA), we now employ these concepts to compare the past and future energy supply risks of the G7 countries. The risks r_j of supply disruptions in individual export countries are identified primarily by applying the OECD (2008) system used for assessing country credit risks, where countries are classified into eight risk categories (0-7), with 7 standing for the highest risk category. Examples of these country-specific classifications, which have been re-weighted here to fall within the range of zero to unity, are displayed in Table 1 of the appendix. Although these classifications are commonly used to gauge loan loss risks, they should satisfactorily characterize a country's political and economic situation, as political risks and other risk factors are also integrated into the OECD assessment.

These classifications are assumed here to remain inter-temporally constant, an assumption that turns out to be inconsequential, as the classification of an individual country hardly changes over time. Alternatively using the contemporaneous classification of each country leaves our results almost unaltered. Furthermore, our calculations are based on the assumption that nuclear power, as well as renewable energy sources, should be treated as a domestic resource. The explanation for this treatment is that nuclear fuels are frequently imported in times when prices are low and stored up to several decades before used in nuclear power plants. This treatment of nuclear fuels as quasi-domestic energy source is also the prevailing practice in international energy statistics.

Using the country-specific primary energy mixes reported in the appendix, as well as the fuel import shares that can be obtained from the IEA statistics, the application of risk indicator (5) reveals that Germany's and Italy's energy supply risks rose substantially over the period from 1978 to 2010, whereas France and Japan have managed to reduce their risks dramatically, thereby reaching an almost similarly relaxed energy security situation as the U. S. and the U. K. (Figure 1). Together with Canada, whose energy supply risk is close to zero, these are the resource-rich G7 countries.

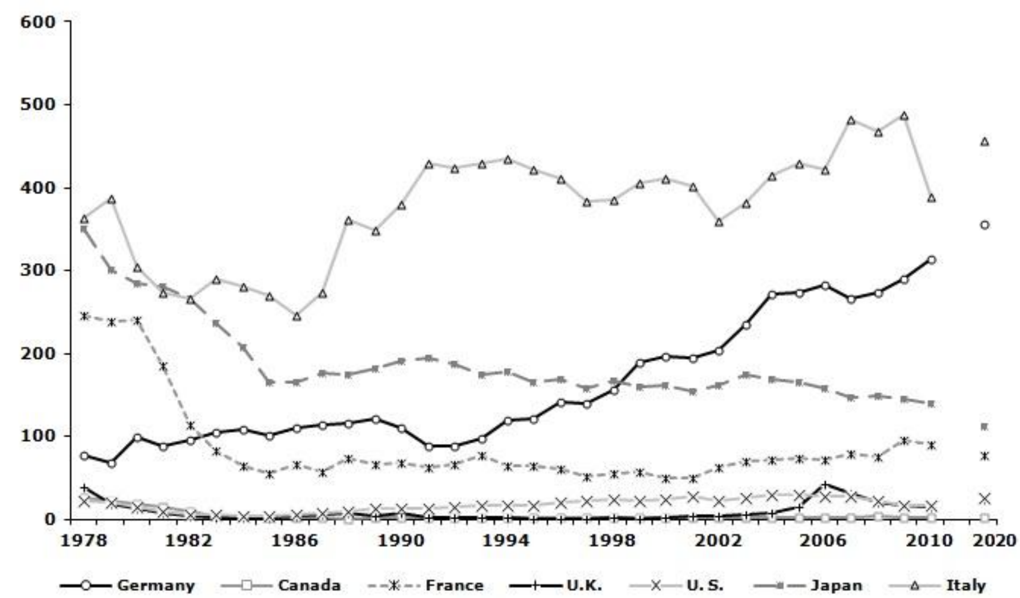

Figure 1: Long-term Primary Energy Supply Risks of G7 Countries (Reference Point: Germany 1980:100).

Today, Germany's energy supply risk is only surpassed by that of Italy. In the past, this was not always the case: At the beginning of the 1980s, France and Japan exhibited much larger energy supply risks than Germany. In contrast to Germany, though, France has been able to reduce its risk, above all through the massive deployment of nuclear power plants. As a consequence, the contribution of nuclear power to the primary energy mix increased from about 8% in 1980 to 42.3% in 2010 (see Table 2 of the appendix), whereas the share of oil decreased from about 56% to some 30% between 1980 and 2010. Among all G7 countries, France displays by far the largest share of nuclear energy, being one major reason for its rather relaxed supply situation today.

Japan reduced its energy supply risk in comparable dimensions as France. Part of the story has been an increase in the share of nuclear power, from about 6% in 1980 to slightly more than 13% in 2010 (see Table 3). In addition, in line with the government's formal energy security strategy of the 1970s that – amongst other things – consisted of reducing dependency on petroleum and diversifying domestic energy supply (Sovacool, Brown, 2010:97), Japan improved the diversity of supply by increasing the relative contributions of natural gas and hard coal. In this way, the former dominance of oil was diminished substantially, with the oil share being reduced from about 75% to 46% in 2010. Not least, Japan spread its gas imports among a growing number of exporting countries, thereby achieving a significant reduction of its gas-specific risk (Figure 2). Brown coal, finally, is not used at all due to the lack of any reserves in Japan, while renewable energy technologies play only a minor role so far.

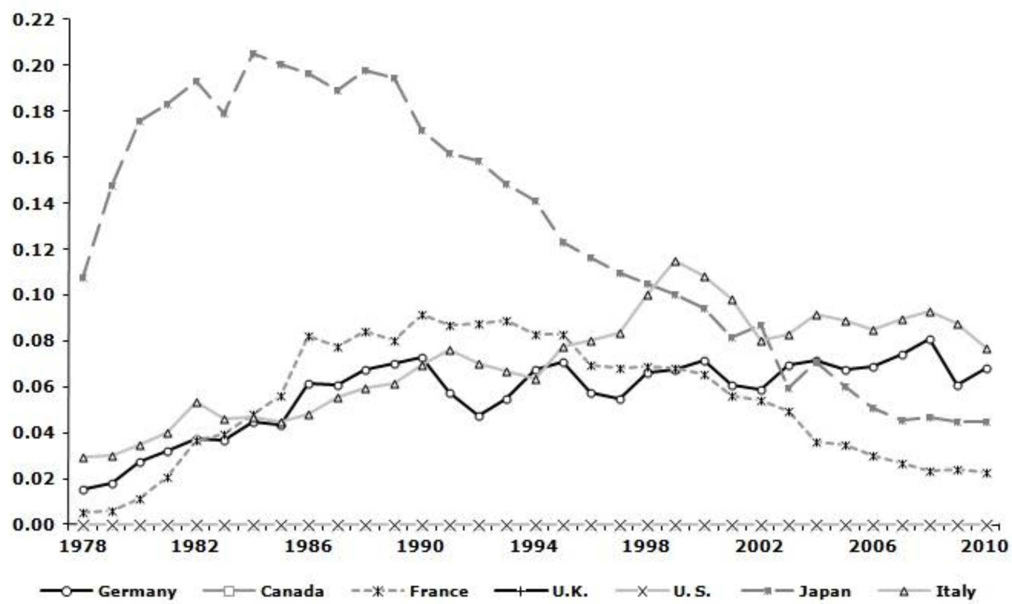

Figure 2: Gas-Specific Risks.

In sharp contrast to Japan's diversification strategy, Germany's imports of oil and gas have concentrated more and more on Russia, thereby substituting the former dependence on OPEC oil with a strong reliance on Russia's oil, gas, and coal reserves. At present, Russia is by far Germany's most important oil provider, being responsible for as much as about 40% of total oil supply. As a consequence, Germany's oil supply risk – in terms of the fuel-specific indicator (1) – has more than doubled between 1980 and 2010 (Figure 3). Furthermore, the drastic decline of Germany's relative contribution to its domestic gas supply has been encountered by surging gas imports from Russia. The current contribution of Russia to Germany's gas supply amounts to about 35% and, hence, is virtually as high as Russia's oil supply share. By contrast, Russia's abundant energy reserves played only a minor role for Germany in the 1970s. As a consequence, Germany's gas supply risk has more than doubled since then, being now higher than Japan's gas-specific risk (Figure 2).

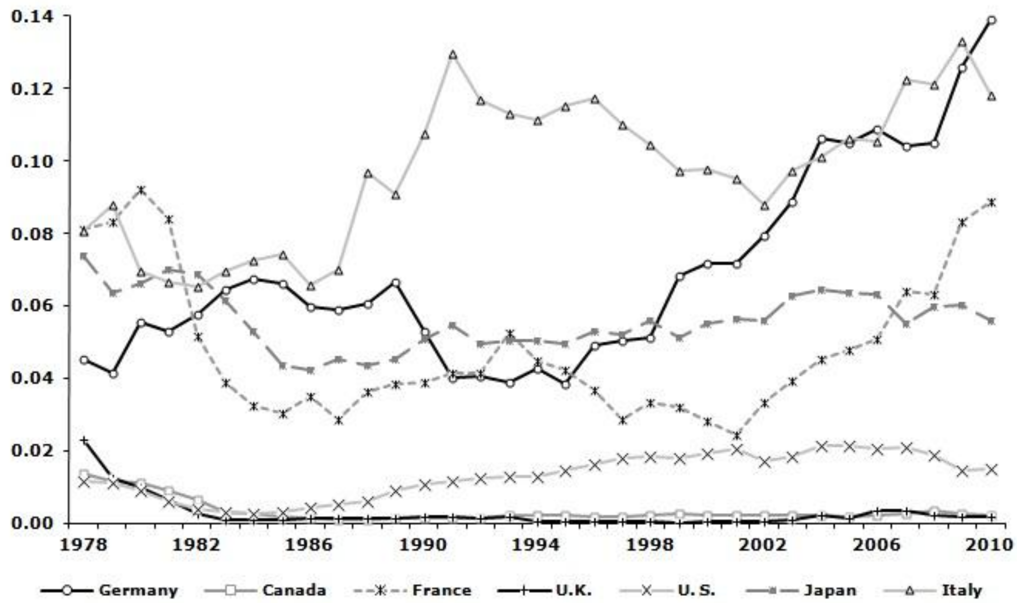

Figure 3: Oil-Specific Risks.

That Germany's energy supply risk has grown substantially since the oil price crises of the 1970s has another reason in the decline of German hard coal production. This decline is due to the large gap between domestic production cost and world market prices of coal (Frondel et al. 2007). Within the next decades, Germany's long-term energy supply risk is likely to rise much further: Given the nuclear phase-out decision of 2011, which stipulates the end of nuclear power in Germany at 2022, and the foreseen dismantling of the hard coal subsidies by 2018, our calculations suggest that Germany's energy supply risk can be expected to rise even if the national goal of a 35% share of electricity production from renewable energies will be reached in 2020 (Figure 1). A major reason is that, based on the present share in electricity production of about 20%, the required increase in "green" electricity is much lower than the contribution of nuclear power, which amounted to almost 25% in 2010. By contrast, given the projections for 2020 presented in Table 4 and the other tables of the appendix, our calculations of the future energy supply risks of other G7 countries indicate that their risks either stagnate or further decrease, as is forecasted for Italy for example.

Similar to Germany, the long-term supply risk of Italy has increased significantly over the last decades. Italy displays by far the highest energy supply risk across G7, owing primarily to its lack of resources and its highly undiversified energy mix: For Italy, brown coal and nuclear energy do not contribute to the energy supply at all, while oil and gas play an overwhelming role (Table 5). It is thus all the more critical that Italy depends so heavily on oil and gas imports, with import shares amounting to 94% and 90%, respectively. It is not surprising, therefore, that the oil- and gas-specific risks of Italy are the highest among all G7 countries (see Figures 2 and 3), as well as the fuel-specific risk regarding hard coal (Figure 4). The hard-coal specific risk has increased substantially since 2000 due to the rising share of imports from Indonesia, which increased from some 10% to about 30% in 2010, whereas the hard coal imports from highly reliable countries such as Australia, Canada, and the U. S.

shrank. With the highest risks with respect to oil, gas, and hard coal, it is no wonder that Italy faces the highest energy supply risk altogether.

Relative to the risk values of Italy and Germany, there is a large gap between the energy supply risks of both these nations and the resource-rich countries of the U.K., the U.S. and Canada. While Canada's supply risk has remained negligible for decades, the U.S.'s risk has risen moderately since the oil crises of the 1970s. Mainly, this increase can be attributed to the growing share of oil imports due to the decline in domestic oil production, resulting in an increase of the oil-specific risk (Figure 3). In contrast, the coal- and gas-specific risks appear to be insignificant. Given these low risk judgments, the enormous efforts in producing bio-ethanol, derived mainly from maize and spurred by tax incentives (IEA 2006d:387), seem to be irrelevant for energy security reasons. In 2006, the U. S. became the world's largest producer of bio-ethanol (IEA 2006d:387), thereby employing large fractions of more than one third of its annual maize production for this task.

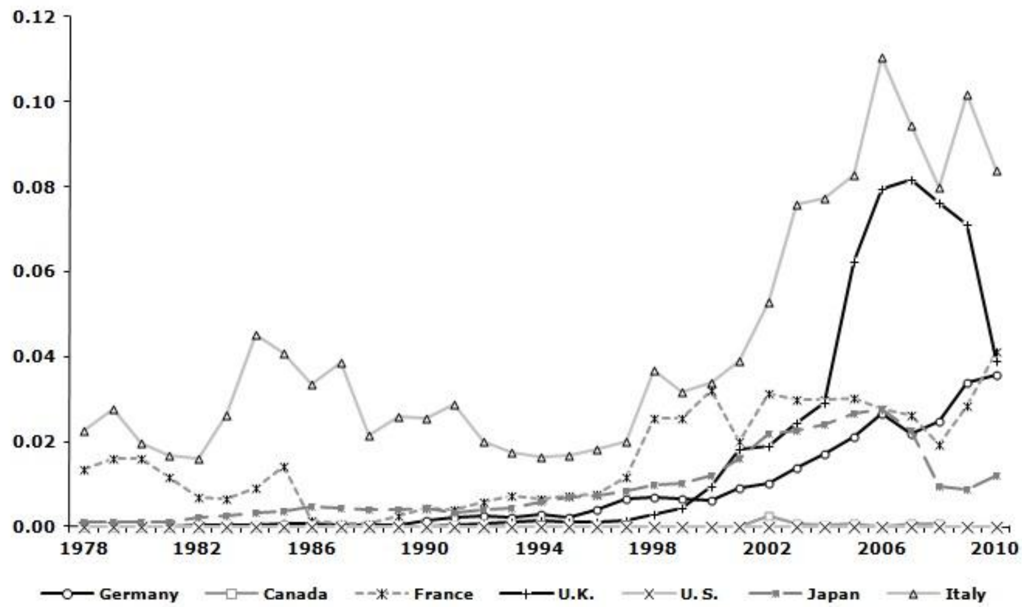

Figure 4: Hard Coal Risks.

In the U. K., finally, there has been a moderate increase in the total energy supply risk of the U. K., most notably because the hard coal risk has grown significantly (Figure 4), whereas the oil- and gas-specific risks have remained zero. One reason for the increase in the hard coal risk between 1995 and 2007 was the declining domestic production. Its share in total supply fell from 77% in 1995 to 30% in 2007. The other reason for the increase in the hard coal risk was the increasing dependence on coal imports from Russia and South Africa. Whereas the U. K. imported a negligible share of 0.2% of its coal demand from each of these countries in 1995, until 2007, the share of Russian and South African imports had grown to 37.3% and 20.8%, respectively. The sharp decline in the U. K.'s hard coal risk between 2007 and 2010 can be ascribed to the lowered dependence on Russian and South African coal imports, which declined markedly to 21.8% and 1.7%, respectively. During these four years, the domestic hard coal production recovered and increased to 41%.

4. Summary and Conclusion

Applying Frondel and Schmidt's (2009) risk indicator to primary energy data of the G7 countries, this article suggests that these countries can be classified into three groups concerning their long-term primary energy supply risks. The first group consists of the energy-rich countries Canada, the U. K. and the U. S., whose energy security situation appears to be rather relaxed: The calculated risk values are quite moderate and stable. Most important for this result is that, although not entirely self-sufficient, these countries' fuel imports are spread among relatively stable exporting countries.

France and Japan, the members of the second group, have managed to reduce their risks by increasing the share of nuclear power, which was the dominant strategy of France, and diversifying both their primary energy mixes and supply structures, a strategy that has been successfully pursued in Japan. Germany and Italy, finally, are the only G7 countries whose energy supply risks rose substantially over the period from 1978 to 2010. Among other reasons, in Italy this was due to the phase-out of nuclear power, which is treated here, as well as in international energy statistics, as a quasi-domestic resource.

Partly, our results are in sharp contrast to the quantitative findings of other studies, such as Sovacool and Brown (2010), who conclude that the U. S. has the lowest energy security of all the 22 OECD countries incorporated in their analysis. This outcome, which is quite the opposite of our finding, is due to the discrepancies with respect to the dimensions of energy security considered. While our analysis has a clear focus on the aspect of physical availability, the study of Sovacool and Brown (2010) takes account of four dimensions, availability, affordability, energy efficiency, and environmental stewardship. It is particularly the environmental dimension, measured by the absolute emissions of sulfur and carbon dioxides, that contributes to the poor performance of the U. S. in the analysis of Sovacool and Brown (2010:93). Actually, the U. S. is one of the two largest contributors to these environmental externalities in the world.

All in all, though, our qualitative analysis of the primary energy mixes and the diversification of fuel imports substantiates our risk calculations, thereby reconfirming the picture drawn in Figure 1. With particular respect to Germany, a key reason for the increased energy supply risk is its strong dependence on Russian oil and gas, and, most recently, its increased hard coal imports from Russia. At present, Russia is by far Germany's most important oil and gas provider, being responsible for as much as about 40% of total oil supply and about 35% of total gas supply. With the recent completion of the new gas pipeline called Nord Stream that traverses the Baltic Sea and ends in Germany, it is most likely that Western Europe's reliance on Russian gas will grow much further, not least due to the shrinking gas production of the U. K. and the Netherlands.

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APPENDIX

Table 1: Normalized OECD Risk Indicators.

Country	Risk	Country	Risk
Algeria	3/7	Netherlands	0
Angola	6/7	Nigeria	6/7
Canada	0	Norway	0
China	2/7	Poland	2/7
Colombia	4/7	Russia	3/7
Ecuador	1	Saudi-Arabia	2/7
Germany	0	South Africa	3/7
Iran	6/7	U.S.	0
Iraq	1	United Arab Emirates	2/7
Kuwait	2/7	United Kingdom	0
Libya	1	Venezuela	6/7
Mexico	2/7	Others	1

Sources: OECD (2008). Note: 1 stands for extremely instable countries, whereas 0 indicates extremely stable countries.

Table 2: France's Primary Energy Mix.

	1978	1980	1985	1990	1995	2000	2005	2010	2020
Oil	61.1	55.9	40.6	38.4	35.3	33.9	33.1	29.6	32.1
Gas	10.1	11.2	11.9	11.4	12.3	13.9	14.9	16.3	14.8
Hard Coal	16.1	16.6	12.2	8.5	6.7	5.8	5.2	4.6	4.5
Nuclear Power	4.3	8.2	28.3	36.0	40.8	42.0	42.6	42.3	41.6
Brown Coal	0.4	0.4	0.3	0.4	0.2	0.0	0.0	0.0	0.0
Renewables etc.	8.0	7.7	6.7	5.3	4.7	4.4	4.2	7.2	7.0

Note: Shares are based on IEA (2004(abc), 2006(abc), 2011(abc)). Renewables include hydro-, wind-, and solar power as well as biomass. Shares for 2020 are based on COM (2008b).

Table 3: Japan's Primary Energy Mix.

	1978	1980	1985	1990	1995	2000	2005	2010	2020
Oil	74.9	68.0	55.8	57.1	53.7	50.4	47.4	46.0	36.3
Gas	4.7	6.2	9.6	9.9	10.6	12.6	13.4	15.9	18.4
Hard Coal	13.9	17.2	19.7	17.4	17.7	17.5	21.0	21.9	21.5
Nuclear Power	4.6	6.2	11.9	11.8	15.2	16.1	15.0	13.2	18.5
Brown Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Renewables etc.	1.9	2.4	3.0	3.8	2.8	3.4	3.2	3.0	5.3

Note: Shares are based on IEA (2004(abc), 2006(abc), 2011(abc)). Renewables include hydro-, wind-, and solar power as well as biomass. Shares for 2020 are based on COM (2008b).

Table 4: Germany's Primary Energy Mix.

	1978	1980	1985	1990	1995	2000	2005	2010	2020
Oil	45.0	40.8	34.3	35.3	39.6	38.3	37.5	31.8	35.2
Gas	13.3	14.2	13.5	15.4	19.6	20.9	23.4	24.0	25.3
Hard Coal	15.9	17.5	16.2	15.5	14.8	13.4	12.5	12.1	9.2
Nuclear Power	3.2	4.0	10.0	11.2	11.7	12.9	13.2	11.1	4.1
Brown Coal	22.6	21.7	24.0	20.6	11.9	11.3	11.1	11.0	8.6
Renewables etc.	0.0	1.8	2.0	2.0	2.4	3.2	2.3	10.1	17.6

Note: Shares are based on IEA (2004(abc), 2006(abc), 2011(abc)). Renewables include hydro-, wind-, and solar power as well as biomass. Shares for 2020 are based on COM (2008b).

Table 5: Italy's Primary Energy Mix.

	1978	1980	1985	1990	1995	2000	2005	2010	2020
Oil	70.6	69.4	61.0	58.5	57.7	51.3	44.2	39.0	40.0
Gas	16.6	16.3	20.0	25.6	27.7	27.7	38.0	39.9	40.2
Hard Coal	6.8	8.4	11.2	9.6	7.6	7.6	8.9	8.2	9.4
Nuclear Power	0.9	0.4	1.3	0.0	0.0	0.0	0.0	0.0	0.0
Brown Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Renewables etc.	5.1	5.5	6.5	6.3	7.7	7.7	8.9	12.9	10.4

Note: Shares are based on IEA (2004(abc), 2006(abc), 2011(abc)). Renewables include hydro-, wind-, and solar power as well as biomass. Shares for 2020 are based on IER, RWI, ZEW (2010).

Table 6: U. S.'s Primary Energy Mix.

	1978	1980	1985	1990	1995	2000	2005	2010	2020
Oil	48.5	44.4	43.4	40.0	38.4	38.7	40.7	36.2	39.3
Gas	24.4	26.3	23.1	22.8	24.4	23.8	22.0	25.3	21.0
Hard Coal	14.9	20.0	18.9	22.4	24.3	22.6	22.0	25.3	21.5
Nuclear Power	4.1	3.8	7.0	8.3	7.9	9.0	9.1	9.8	9.4
Brown Coal	0.6	0.8	1.3	1.3	1.3	1.0	1.1	1.0	1.0
Renewables etc.	7.5	3.4	6.3	5.2	3.7	4.9	5.1	2.4	7.8

Note: Shares are based on IEA (2004(abc), 2006(abc), 2011(abc)). Renewables include hydro-, wind-, and solar power as well as biomass. Shares for 2020 are based on IEA (2008).

Table 7: U. K.'s Primary Energy Mix.

	1978	1980	1985	1990	1995	2000	2005	2010	2020
Oil	45.4	40.8	38.7	38.9	37.9	36.2	36.1	31.9	39.0
Gas	17.6	20.0	22.9	22.2	29.2	37.8	36.5	41.5	34.5
Hard Coal	32.2	34.2	30.5	29.7	21.0	14.8	16.2	15.0	17.4
Nuclear Power	4.6	4.8	7.8	8.1	10.4	9.6	9.1	8.0	3.3
Brown Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Renewables etc.	0.2	0.2	0.2	1.0	1.5	1.6	2.1	3.6	5.8

Note: Shares are based on IEA (2004(abc), 2006(abc), 2011(abc)). Renewables include hydro-, wind-, and solar power as well as biomass. Shares for 2020 are based on COM (2008b).

Table 8: Canada's Primary Energy Mix.

	1978	1980	1985	1990	1995	2000	2005	2010	2020
Oil	48.5	46.1	36.3	36.9	33.6	33.6	35.0	35.9	35.9
Gas	24.4	23.6	25.8	26.2	26.2	29.1	29.6	30.2	30.2
Hard Coal	6.4	7.0	7.3	5.4	5.4	4.4	5.3	2.9	2.9
Nuclear Power	4.7	4.1	8.4	9.3	9.3	11.0	8.8	9.2	9.2
Brown Coal	3.0	3.5	5.7	5.3	5.3	6.2	5.4	5.7	5.7
Renewables etc.	13.3	15.7	16.5	16.9	16.9	15.7	15.4	16.1	16.1

Note: Shares are based on IEA (2004(abc), 2006(abc), 2011(abc)). Renewables include hydro-, wind-, and solar power as well as biomass. Shares for 2020 are identical to those of 2010 by assumption.