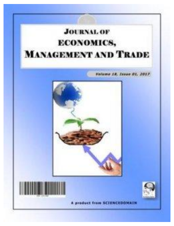

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Electricity Market Risk Premia: Evidences from Developing Power Exchanges in Central and Eastern Europe

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

This paper aims to investigate the adequacy of risk premium approach for developing power exchanges in Central and Eastern Europe, namely Power Exchange Central Europe and Polish Power Exchange. For the purposes of the research, we use data for base load and peak load month futures to calculate and analyze absolute and relative risk premia. Also the term-structure and time-evolution of the risk premium is assessed. Using a data set covering period of three years from introduction of futures contracts in to the trading schedule of chosen power exchanges, it was found that patterns of electricity risk premia at developing markets differs than one observed for developed ones.

Keywords: Electricity derivatives; risk premium; electricity market.

1. INTRODUCTON

Electricity market liberalization fundamentally changed business model of power producers and consumers operating in these markets. In contrast to the positive macroeconomic effects of liberalization, such as overall price decrease for all consumer ty pes, on the level of individual

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power producing company liberalization introduced uncertainties to day to day business. Major negative effect of electrcitiy market liberalization is an increase of idiosyncratic risks, where most dominant are electricity price risk, following credit, liquidity and regulatory risk. The research conducted among twenty one power producing companies shows that the key risk in liberalized electricity market is electricity price risk [1]. In that respect, it is important to address the issue of reducing price risk through financial derivative products and their pricing models.

As non of the well known models for pricing derivatives in financial market are not directly applicable to pricing electricity derivatives, it is important to investigate applicable models for pricing electricity derivatives. Electricity posses the unique characteristic of non storability which makes cost-of carry approach unusable for pricing electricity futures. Bessembinder and Lemmon [2] wrote the most influential theoretical paper on electricity futures, where they develop an equilibrium model for electricity forward pricing using risk premium approach [2]. As it is argued by Pietz, from an equilibrium point-of-view the risk premia approach seems to be most promising for explaining the price formation for electricity derivatives.

Based on the research of Bessembinder and Lemmon many authors investigated risk premia across power exchanges around the world with general conclusion that electricity futures markets have positive short-term risk premium and negative long-term risk premium [2-16].

To further analyze the adequacy of risk premium approach, research in this paper is extended to developing power exchanges of Central and Eastern Europe. The aim of this paper is to empirically test of the risk premia approach at Power Exchange Central Europe and Polish Power Exchange. For the purpose of this research we use data set covering period from introduction of futures derivatives in the above mentioned power exchanges in 2008 up to the end of 2011. Risk premia approach is analyzed from the perspective of ex-post risk premia, and also the term-structure and time-evolution of the risk premium is assessed.

This paper is organized as follows: The second section provides a literature review of up-to date research on electricity market risk premia. The third part of the paper deals with mathematical background of calculation of risk premia. In the fourth part of the paper the discussion of the results of risk premia for chosen power exchanges is presented, as well as the comparison of risk premia in developing and developed electricity markets.

2. PREVIOUS RESEARCH ON THE ELECTRICITY MARKET RISK PREMIA

Previous research on electricity risk premium discussed characteristics and the sign of risk premium. While some of the research analyzed short-term risk premium (risk premium calculated based on day-ahead and intra-day price of electricity), other discussed long-term risk premium (risk premium for week and month future contract).

Most influential research on short-term risk premium are published by Bessembinder i Lemmon [2], Longstaff and Wang [3], te Diko et al. [4] etc. Bessembinder and Lemmon concluded that in case of expected low demand and decreased risk related to electricity demands results in negative risk premiums, while in case of increase in demand and risk associated with that demand results in positive risk premiums. Other research provide similar conclusion on short-term risk premium and point that short-term premium vary during the day and is volatile.

Botterud et al. [7], Shawky et al. [8], Bierbrauer et al. [5,9], Wilkens & Wimschulte [10], Lucia & Torro [11], Torro [12], Kolos & Ronn [13], Furio & Meneu [14], Marckhoff & Wimschulte [15] published research on long-term risk premium.

Botterud et al. [7], Lucia i Torro [11] i Torro [12] investigated risk premium at Nord Pool electricity exchange. These researches showed positive risk premium for futures with time to delivery of one year and one week. Marckhoff and Wimschulte [15] analyzed risk premium for contract for differences (CfDs) at Nord Pool and showed positive risk premium for short term contract and negative for long term. Furthermore, Shawky et al. [8] analyzed risk premium for electricity futures for California – Oregon region, which are traded at NYMEX, and also established positive risk premium. On the other hand, research on risk premium for Iberian markets showed negative ex.post risk premium Furio & Meneu, [14]. Research on risk premium for EEX conducted by Wilkens & Wimschulte [10], Bierbrauer et al. [5], Kolos & Ronn [13] and Pietz [16] showed similar results as one obtained for Nord Pool.

Based on the above discussed researches, the following concussions regarding risk premium patterns can be made:

- Short-run risk premium (at day-ahead market) is positive, due to the fact that buyers (consumers) try to hedge risks related to sudden electricity price jumps, and therefore are willing to pay premium in short run to lock in the price of electricity consumed. This means that producers may achieve additional profits by concluding short term electricity future contract.
- Long term risk premium have negative sign due to the fact that producers try to hedge future electricity production. Producers prefer long term – quarterly or yearly contracts. By concluding long term contract, producers bear losses in the amount of risk premium.
- In unpredictable situations and market conditions (shortages due to the producers equipment malfunction, weather conditions or congestions) sign of risk premium may vary.

The existence of risk premium at electricity markets is a sign of possibility to gain additional profits from the trade at electricity derivative markets. But, as mentioned since electricity have the property of non-storability, risk premium existence also means that electricity market are not efficient as is case of financial markets. In terms of financial markets efficiency notation– electricity markets have a weak form of price efficiency. Risk premium shows rational behavior and risk aversion of market participants.

Due to the unique characteristics of a particular electricity market, it is not possible to generalize results obtained by previous studies, which is indicated in the work of Longstaff & Wang.

On the other hand it possible to make assumption that similar electricity exchanges (for example: similar degree of development, regional connection, similar production mix) can shows similar patterns of risk premium. Therefore, in the next part of this paper, this assumption is being tested for electricity exchanges with similar characteristics.

3. THEORETICAL AND MATHEMATICAL BACKGROUND ON ELECTRICITY PRICE RISK PREMIA

According to the relevant financial literature, future price of a contract for delivery of electricity, or more precisely, price of the standardized future contract at electricity market cannot be determined by using the traditional cost-of-carry approach [17][1].

While modeling of future price for financial and commodity assets is possible by using standardized cost-of -carry approach, modeling of future price for electricity needs different approach due to the specific nature of electricity. Electricity cannot be stored and needs to be consumed in the moment of its production. This characteristic of non-storability implies that price of the electricity to be delivered in the future cannot be determined in advanced (before the moment of actual production).

Theory suggests that accepted model for determining the price of the futures contract (in other words, relation between spot and future price of electricity) is the risk premia model or the risk premia approach [16].

Risk premium for futures contract on electricity can be calculated using the following formula (1):

$$\pi(t,T) = F(t,T) - E_t\left[S(T)\right], \tag{1}$$

[1] *Cost of carry approach uses cost of carry to explain the difference between future and spot price, where cost of carry of holding financial asset in a portfolio (or in case of commodities cost of storage) plus interest paid for holding a asset and minus the revenues collected in relation to holding a asset (such as dividend income on stocks).*

Traditional mathematical formula for calculating the price of the future (forward) contrat, based on the cost of carry (buy and hold strategy) for finanical asset, can be written as follows:

$$F_0 = S_0 e^{cT},$$

While, the price of a commodity futures (forward) contrat can be callculated based on the following formula:

$$F_0 = S_0 e^{(c-y)T},$$

where:
F_0 is a price of the futures contract,
S_0 is a price of the underlying asset in the moment t = 0,
c is a cost of carry,
y is a convenience yield,
T is a days to maturtiy of the futures contract.

Where:

π(t,T) is risk premium in moment t for futures contract with delivery date T*,*
F*(t,T)* is price of the futures contract with delivery date T, in moment t,
E_t [S*(T)*] is expected value of the spot price in moment T (for delivery period).

Model of calculation risk premium where expected value of the spot price of electricity is used for calculation is called model of *ex-ante* risk premium.

For adequate use of *ex-ante* risk premium model it is necessary to chose appropriate model for modeling electricity spot price. But, modeling of electricity spot price is a complex process, where most of the used models cannot accurately predict electricity spot price movements. In order to avoid the problem of predicting a future electricity price, a model of *ex-post* risk premium can be used for determination of electricity risk premium.

According to ex-post risk premium model, electricity risk premium can be calculated using the following formula (2):

$$\pi(T) = F(t,T) - S(T)\,, \tag{2}$$

Where *π(T)* is risk premium calculated in the moment of futures contract delivery.

Relation between ex-ante and ex-post premium can be expressed through the following formula (3):

$$F(t,T) - S(T) = \pi(t,T) + \varepsilon_t\,, \tag{3}$$

Where ε_t is average standard error or stochastic component associated with low predictability of electricity spot price.

If assumed that market participant are rational in forming their expectation, ex-ante risk premium is equal to ex-post premium, where $\varepsilon_t = 0$.

With above set precondition, ex-post risk premium in electricity market can be, further, calculated:

$$\pi(T) = \frac{1}{T}\sum_{t=1}^{T}\left(F(t,T) - S(T)\right), \tag{4}$$

Where, S*(T)* is average price of hourly prices during delivery period for particular electricity futures contract.

Risk premium calculated using defined formula is call absolute risk premium. The absolute risk premia can be interpreted as the amount of money paid by the producers or consumers (depending on the sign of premium) expressed in the currency at which future contract is quoted at power exchange.

Also, it is possible to calculate relative risk premium. Relative risk premium is a percentage of the electricity price paid through the futures contract to hedge price risk. Relative risk premium can be used for comparison with risk premiums for same contract on different power (electricity) exchanges.

Mathematical representation of relative risk premium is:

$$\pi_{rel}(T) = \frac{1}{T}\sum_{t=1}^{T}\left(\frac{F(t,T) - S(T)}{F(t,T)}\right) \tag{5}$$

The adequacy of the risk premium approach for electricity futures prices suggests that the futures prices cannot be seen as unbiased estimators of the expected future spot price. Rather they reflect the demand and supply for hedging instruments [18].

4. CASES OF ELECTRICITY MARKET RISK PREMIA AT POWER EXCHANGE CENTRAL EUROPE (PXE) AND POLISH POWER EXCHANGE (POLPX)

4.1 Data Collection and Methods Used for Risk Premia Calculation

According to the theoretical background presented in the first part of the paper we use mathematical formulations (4) and (5) presented to calculate risk premium absolute and relative *ex-post* risk premium. For the purpose of comparison of electricity market risk premium in developing electricity markets, data were calculated for Power Exchange Central Europe and Polish Power Exchange[2].

[2] *Data for PXE were obtained with the approval of Director of External Comunications of PXE Mr. Jiří Kovařík. (Prague Stock Exchange, Member of the CEE Stock Exchange Group, 110 05 Praha 1, Rybná 14,*
Data for POLPX are available at the Exchange web site www.polpx.pl

Risk premium for Power Exchange Central Europe was calculated based on 20 month futures for electricity covering January 2010 to August 2011. Data analysis shows that future contract for January 2011 is the first liquid futures for both load profiles (base and peak). Futures contract for electricity delivery in Czech Republic are used based on the fact that this is a most liquid market segment. For PXE we calculated risk premia six, five, four, three, two and one month to delivery of future contact.

Risk premium for Polish Power Exchange was calculated based on the series of 18 month futures contracts for base load covering period from June 2010 to December 2011. Base load future contracts at POLPX were introduced in December 2008, but first liquid traded base load future contract was June 2008. Furthermore, risk premium on peak load future contacts was calculated for 16 month futures from August 2010 to August 2011. In case of POLPX, we calculated risk premia three, two and one month to deliver of future contract.

4.2 Patterns of Electricity Market Risk Premia at PXE and POLPX

Based on the historical data of electricity prices at PXE we found the following patterns of risk premia. Risk premia for base load month futures is negative for almost the most part of the observed period. We found positive risk premia in August of 2010 for future contracts with three or less months to the delivery date. Risk premia was positive again in the summer months of 2011 (June, July and August) for futures with time to delivery of more than a month. (Fig. 1.) Risk premia for peak load month futures shows the same pattern as base load risk premia, but is significantly negative in fifth and twelve month. In summer months is positive for periods to the delivery. (Fig. 2.)

Based on the calculation of risk premium at POLPX, we found negative risk premium in winter months with lowest value for December futures, while positive risk premium was observed in summer months June, July, August and, even, September (Figs. 3 and 4).

As it can be observed from illustrations presented above, it can be concluded that risk premiums at both power exchanges and for both load profiles show the same patterns.

4.3 Absolute and Relative Market Risk Premia at PXE and POLPX in Comparison to Developed Electricity Exchanges

Tables 1 and 2 shows comparison of average value of absolute ex-post risk premia for month base load and month peak load future for chosen power exchanges.

Tables 3 and 4 shows comparison of average value of Relative ex-post risk premia for month base load and month peak load future for chosen power exchanges.

In case of EEX, absolute and relative risk premium shows similar characteristics for both types of future contracts. Risk premium is positive in both cases, but it can be observed that the value of the premia increase as the date of delivery approaches. Maximal value of risk premia is two months before the delivery date (for base load futures it is 2,68 Euros per MWh while for peak load futures it is 5,45 Euros per MWh). In case of base load futures, a negative risk premia can be observed only for futures with time to delivery of six months. Research shows that in the case of EEX, buyers (electricity consumers) are willing to pay risk premium in order to hedge electricity price risk, where this need is more pronounced as the time delivery approaches, hence risk premium increase.

Table 1. Absolute risk premia for base load month futures

Time to delivery (in months)	EEX*		PXE**		POLPX**	
	Avg.	*Std. dev.*	*Avg.*	*Std. dev.*	*Avg.*	*Std. dev.*
One	2,3	9,26	-2,2	4,45	-1,79	15,16
Two	2,68	11,97	-2,31	4,95	-2,68	15,87
Three	2,34	12.73	-2,49	5,26	-3,17	15,97
Four	1,54	13,08	-2,89	1,65	-	-
Five	0,73	13,50	-2,58	5,59	-	-
Six	-0,03	13,79	-2,69	5,58	-	-

** Pietz, M. (2009), ** Authors calculations*

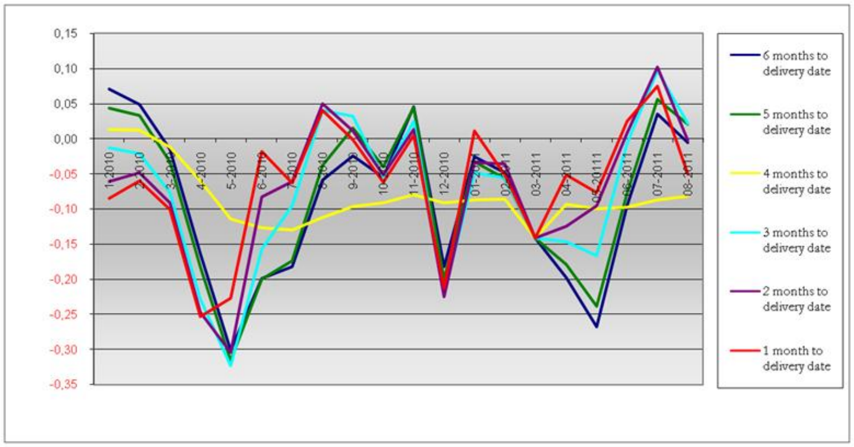

Fig. 1. Relative risk premia for base load month futures at PXE

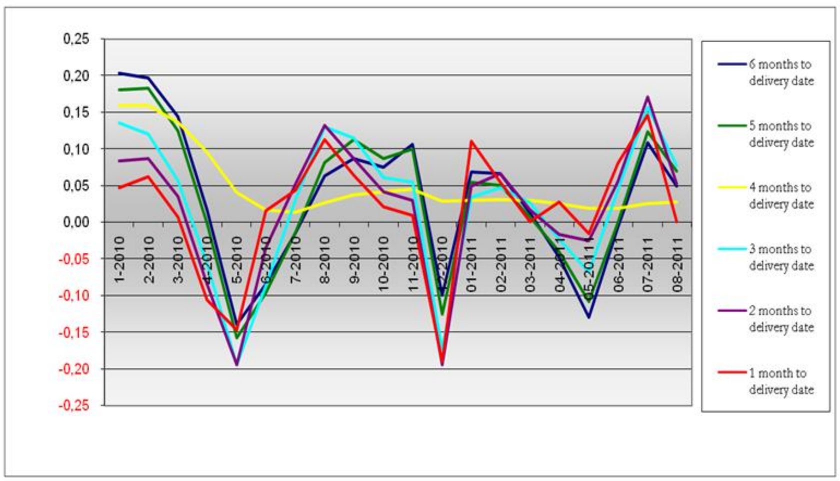

Fig. 2. Relative risk premia for peak load month futures at PXE

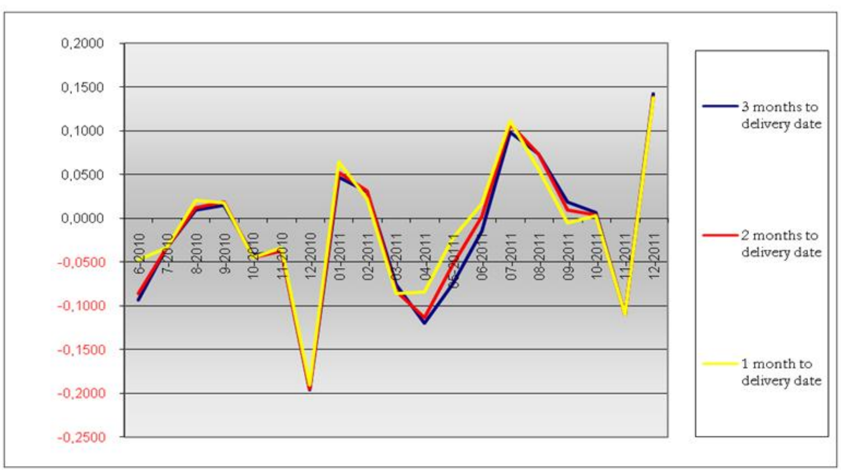

Fig. 3. Relative risk premia for base load month futures at POLPX

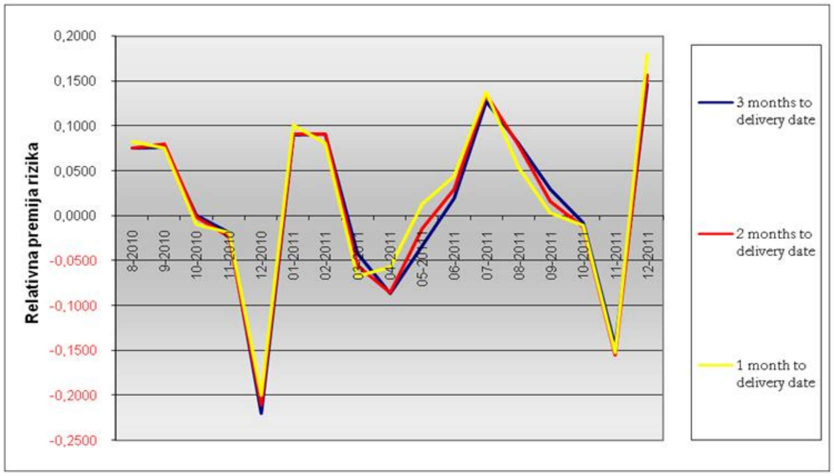

Fig. 4. Relative risk premia for peak load month futures at POLPX

Table 2. Absolute risk premia for peak load month futures

Time to delivery (in months)	EEX*		PXE**		POLPX**	
	Avg.	*Std. dev.*	*Avg.*	*Std. dev.*	*Avg.*	*Std. dev.*
One	4,36	17,09	1,43	4,79	3,87	21,83
Two	5,45	21,30	1,7	5,22	3,05	21,72
Three	4,95	21,75	1,99	5,59	2,88	21,28
Four	3,78	21,52	3,79	2,92	-	-
Five	2,82	21,55	2,54	6,02	-	-
Six	1,97	22,24	2,69	6,12	-	-

** Pietz, M. (2009), ** Authors calculations*

Table 3. Relative risk premia for baseload montly futures

Time to delivery (in months)	EEX*		PXE**		POLPX**	
	Avg.	*Std. dev.*	*Avg.*	*Std. dev.*	*Avg.*	*Std. dev.*
One	3,49	19,75	-6,46%	0,08	-1,13%	0,077
Two	2,93	24,43	-7,09%	0,10	-1,64%	0,081
Three	2	25,19	-7,70%	0,10	-1,91%	0,08
Four	0,28	25,83	-8,30%	0,04	-	-
Five	-1,7	26,52	-8,48%	0,11	-	-
Six	-3,61	27,77	-8,77%	0,11	-	-

** Pietz, M. (2009), ** Authors calculations*

Table 4. Relative risk premia for peak load month futures

Time to delivery (in months)	EEX*		PXE**		POLPX**	
	Avg.	*Std. dev.*	*Avg.*	*Std. dev.*	*Avg.*	*Std. dev.*
One	5,05	25,53	1,78%	0,08	1,52%	0,09
Two	4,96	30,28	2,09%	0,09	1,14%	0,09
Three	4,24	30,37	2,45%	0,09	1,08%	0,097
Four	2,87	29,99	5,05%	0,04	-	-
Five	1,48	30,18	3,18%	0,09	-	-
Six	-0,15	32,33	3,36%	0,09	-	-

** Pietz, M. (2009), ** Authors calculations*

In contrast to risk premium at EEX, data from developing power exchanges shows negative risk premium for base load futures where the negative value of the premium decrease as the date of delivery approaches. This means that power producers at developing markets are more sensitive to electricity price risks and, therefore, are willing to pay the premium for hedging that risk. As the results of absolute and relative risk premium for base load futures for PXE and POLPX shows, risk premium decrease as the date of delivery approach. This, further means that power producers are hedging for the uncertainty of the price in longer terms.

In case of peak load futures, risk premium is positive, which implies that power producers are interested in hedging their base load production, while are ready to gamble on peak load prices. In other words, power consumers are more sensitive on the price movement for the peak load consumption, having in mind that this power is more expensive in all electricity markets (mainly because of insufficient power production capacities characteristic for most of the power markets, as well as the possible congestions of power lines).

5. CONCLUSION

Process of electricity market liberalization stared two decades ago in developed part of the world and in developing countries of Central and Eastern Europe only a 5 years ago, there are were no many studies on the behavior of market participants. Having in mind the potential consequences of electricity market crashes, or shutdowns, such as Californian market crash in 2001, the need for monitoring behavior of different parties at these markets became an important issue.

In this paper we addressed the issue of electricity market player behavior by analyzing a risk premia of particular electricity contracts at the developing electricity markets in Central and Eastern Europe. Risk premia approach was used as a tool for examining the risk appetite of power producers and power consumers.

For the purposes of the research, two major electricity exchanges were chosen: Power Exchange Central Europe and Polish Power Exchange. Due to liquidity considerations, analysis was restricted to month futures at two power exchanges.

The results of the analysis shows that calculated risk premia have different patterns then observed a risk premia observed at developed electricity market, which was shown by comparing obtained results from chosen exchanges to the developed one. In contrast to developed electricity markets, where long-term risk premium is negative and short-term risk premium positive, data shows that sign of risk premium in observed market depend on the load profile not on the time to delivery of future contract.

Based on the risk premia patterns observed at developing exchanges the following conclusions about behavior of the market participants can be made:

- Power producers at developing power markets are more risk averse when it comes to the base load production. The underlying reasons might be the unfamiliarity with market behavior, and more likely the importance of base load production in recovering the production costs (fixed more than variable costs) and gaining targeted normal profit margins.
- Power consumers, on the other hand, express higher risk aversion to the price volatility in periods of higher demand for electricity, when prices spikes and can be even 100% higher than in the off peak period.

One interesting finding was that producers are ready to cut down a portion of their profit to secure the price of produced electricity for base production, while they are more willing to gamble on the price of peak production. These patterns of power producer's behavior are in contrast to observed developed electricity market.

It would be interesting to follow observed behaviors as markets progress in their development in terms of higher liquidity of power products (both spot and derivative) and of increase in market competitions. Further research might shed some light weather the market participant behavior at developing market converge to the behavior of participants at developed electricity markets, or every market (national or regional) has its own behavior patterns. A major reason for not being able to address this latter issue in this paper is the liquidity problem with futures contracts traded at the chosen markets.

Even though, some of the observed products were traded in the markets for 3 to five years, there we no liquid trading. Therefore, the observed time series were rather short, but produced some interesting results and we were able to established patterns of risk premia movements.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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