

A Quantitative Analysis of the Electricity Market in Switzerland

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Abstract—The electricity market in Switzerland began liberalisation in 2008, with the passing of the Federal Electricity Supply Act, and is still not fully liberalised. Owing to its relative immaturity, there is little in the way of centralised reporting of its stylised facts, a situation the current work attempts to rectify. As a guideline, a standard Hourly Price Forward Curve (HPFC) is developed. Since Switzerland does not yet boast a financial index for energy Futures, the implementation of this model is not straightforward. This issue is addressed by a quantitative market analysis based on regionally specific stylised facts. The resulting model also yields insights on the influence of bottom-up factors driving Swiss spot prices, in particular with regards to the relatively high share of hydro-power in Switzerland. We conclude with a discussion of this “Swiss-made” HPFC and its implications for the evolution of the Swiss market.

I. INTRODUCTION

At the November 2010 meeting of the Swiss-American Chamber of Commerce, a report was presented [1] which identified the turbulent switch to a deregulated energy market as a credible threat to the Swiss manufacturing sector. A number of multinational CEOs at the event went so far as to castigate energy liberalisation as a failure, and the resulting price increases as a threat to their continued operations in Switzerland. While this may well have been political posturing, there is no denying that the energy market has changed radically in Switzerland and will continue to change.

In context, the last few decades have seen an accelerated global trend towards the deregulation of national electricity supply, with electric power becoming a commodity traded cross-border on international energy exchanges. As these markets mature, certain regional truisms about the nature of supply and demand, the energy mix, seasonality and the price formation process become accepted as stylised facts of the industry. Numerous recent reports have gathered and summarized this information for different regionally defined markets such as Italy [2], Europe [3], Germany [4], Nordic Countries [5], [6], Canada [7] and Ireland [8] to name a few.

While a number of works on Swiss energy policy and make-up exist [9]–[11], there is little technical literature accounting for recent moves to a more liberalised market. Macro-economic figures are available from the Swiss Federal Office of Energy, e.g. annual consumption lies around 60 TWh and is rising (about 2% pa.) while capacity is decreasing; maximal hydro

storage is just under 9 TWh delivering about 55% (37 TWh) of annual supply — and so on.

Of more interest to this study are facts relating to the partially (2008–2013) and fully liberalised electricity market. From 2014 the 100 MWh annual volume threshold will no longer apply to market participants, and by this time the high-voltage grid (220/380 kV) must be transferred to the national grid company (Swissgrid), under the terms of the Federal Electricity Supply Act. Our focus is on the resulting price-dynamics and how regional stylised facts manifest themselves in observable price series for spot and forward contracts on over-the-counter markets. This point of view is expanded around the modelling of an HPFC trained on the Swiss market.

Section II presents the HPFC model, consisting of a regression on statistical variables to expand implied Futures to an hourly basis. Although this model is easy to implement, it is only apposite if the regression set used can capture the stylized facts of the target country. To explain how this is achieved, the core elements of our chosen regression technique are also presented. The training of the model on Swiss data is discussed in Section III. To address the lack of Futures, a solution relying on the strategic location of Switzerland at the cross-roads of central of Europe is proposed in Section IV. Finally, an interpretation and discussion of these results are presented towards the end of the article.

II. A STANDARD HPFC MODEL

While conventional HPFC models derive from exchange traded Futures in mature markets [12], the lack of an implied Futures curve for Swiss energy precludes such simplicity. Instead, a bottom-up pricing tool based on structural elements of the market is considered, extending an implied Futures curve to an hourly basis, as illustrated in Fig. 1. Indicators are used to classify hours as peak or off-peak, to classify days as workdays, weekends or holidays etc. Other structural elements such as the season of the year and country-based weather time-series are taken as inputs to the model. A regression is used to quantify the historical influence of each factor on price evolution. These values can be projected forward, in conjunction with other market data to derive the HPFC. The 3 key steps to derive the HPFC, as illustrated in Fig. 1, are:

- 1) A regression is performed on two years of daily spot

prices, averaged over hourly spot prices. The explanatory variables consist of weather-related time-series and binary activity indicators. This regression m can be represented as:

$$S(t) = m(W(t), I(t)),$$

with

- $S(t)$: Historical daily spot price.
 - $W(t)$: Daily weather (usually mean temperature and heating indicator).
 - $I(t)$: Daily indicators representing whether the day does or does not belong to known windows of similar activity (e.g. holidays, summer months etc.).
- 2) The explanatory variables are projected to the future using historical seasonal variations. The implied Futures curve can therefore be extended to a daily granularity. To go further and generate hourly variations, hourly profiles are derived linearly from the last two-years of spot prices. The simulation can be represented by:

$$P(t, h) = F(t)[1 + m(t)][p(t, h)]$$

with

- $P(t, h)$: Estimated hourly Future price for day t and hour h .
 - $F(t)$: Future price for day t based on the monthly, quarterly and yearly Futures (peak and off-peak).
 - $m(t)$: Output of the regression based on future indicators and seasonal weather expectations.
 - $p(t, h)$: Daily spot price profile for day t , hour h , based on past years profile.
- 3) During the simulation, the arbitrage-free conditions ensure the final curve is not biased with regards to the market data.
- $E_t[m(t)] = 0$: The regression output is normalized, centred in 0. It makes sure the mean value over the delivery range of the Future is equal to the Future value.
 - $E_h[p(t, h)] = 1, \forall t$: This makes sure the daily variations are on average equal to the value given by the regression.

One essential consideration is that the resulting forward curve must not present arbitrage opportunities for cross-border trade, which is ensured in the model (step 3). This step is, however, entirely deterministic and does not include country-specific elements. On the contrary, step 1 and 2 are regionally specific, and are thus elaborated in Sections III and IV respectively. For a more comprehensive treatment of this model and other aspects of standard HPFC construction, see [13], [14].

Two different regressions are performed in this paper. Both involve the use of highly inter-correlated time-series with heavy outliers. As both regressions are part of a bottom-up model, a variable selection technique is needed for interpretative purposes. To cope with these constraints and requirements,

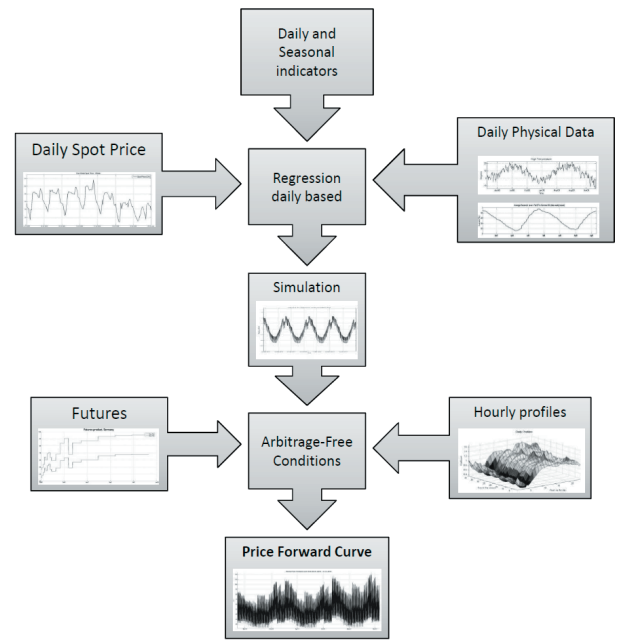


Fig. 1. HPFC Model

a variable selection technique based on the least-absolute-deviation is used, providing more robustness than a classic Ordinary Least Squares criterion [15]. The technique used is based on a l_1 -regularization [16] that controls the bias-variance trade-off in the regression, and is called the lad-lasso (Least Absolute Deviation - Least absolute shrinkage and selection operator) [17].

Consider the usual linear regression model:

$$Y = X\beta + \epsilon, \quad (1)$$

where β is the unknown coefficient vector, X represents the matrix of the explanatory variables, Y is the response or explained variable and ϵ is an error term. The lad-lasso optimization problem is given in canonical form by:

$$\hat{\beta}(s) = \arg \min_{\sum_{j \in [1, p]} |\beta_j| \leq s} \{|Y - X\beta|\}, \quad (2)$$

where p is the 2nd dimension of the factor matrix X and s is the regularization coefficient which controls the amount of shrinkage that is applied to the estimates. In order to get a relatively “tight” and therefore very robust lasso, s is determined with the Bayes Information Criterion-type objective function [17], which tends to shrink insignificant coefficients easily.

III. INFLUENCE OF WEATHER ON SWISS SPOT PRICE

The first step of the HPFC model consists of a regression on the historical spot price with explanatory variables that can be easily extended into the future (e.g. seasonal weather expectations). The most relevant explanatory variables will be picked out by the regression technique. We want to show how

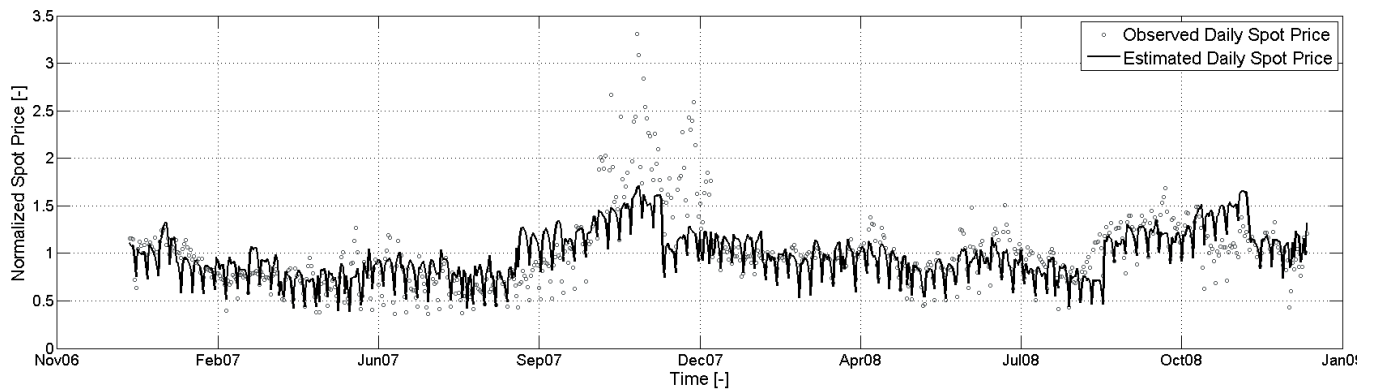


Fig. 2. In-sample fit regression results

this reflects standard qualitative Swiss stylized facts, starting with the influence of hydro-related indicators.

The regression is performed on two-years of daily, normalized spot prices. The explanatory variables consist of binary indicators (seasonal and daily) and weather variables:

- the daily mean temperature,
- the highest temperature of the day,
- the lowest temperature of the day,
- the heating days degrees (HDD),
- the cooling days degrees (CDD),
- the precipitation,
- the wind speed,
- the relative humidity,
- the reservoirs level.

All time-series are provided by Bloomberg and are all national average, apart from the reservoirs level defined as the cumulated volume retained in the main Swiss reservoirs (see Fig. 8). To get reliable results, the variable selection and resulting coefficients are simulated from the beginning of 2009 to the end of 2010, with a 15 days moving window, resulting in about 40 regression results based on overlapping training sets. A typical regression is pictured in Figure 2.

The variable selection results is of interest because it can reflect market specificities. Fig. 3 represents the variable selection results for weather indicators over the set of regressions performed. As a benchmark, the French and German variable selection results are also displayed. Although it could have been selected, the Swiss Reservoir Level indicator is not included for the French and German simulations as it is not structurally meaningful. The other time-series are the national average of each countries. Since hydro-electric power constitutes about 56% of the Swiss energy mix, the selection of the reservoir level as a price-influencing factor is expected from a qualitative point of view. Even though it is selected for some regressions, it appears to be overall not the most relevant variable ($\sim 42\%$). The relative humidity and precipitation variables, which directly impact the snowfall and the run-of-river power plants, are also not significant in comparison with the German market. Surprisingly, Switzerland gets very

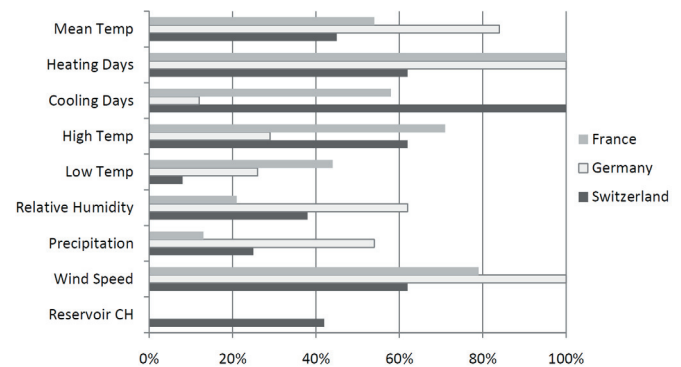


Fig. 3. Weather variable frequency of selection results. The x-axis represents the frequency of selection of the variables among each simulation performed.

distinct selection results for the cooling indicator. Fig. 4 represents the reservoir level's coefficient evolution over the backtest, from the oldest period to the most recent. Consistent to a qualitative analysis, the coefficient is at first negative, implying that an increase in reservoir level will push the prices down. As it is set to 0 almost all the time afterwards, a clear market evolution is apparent.

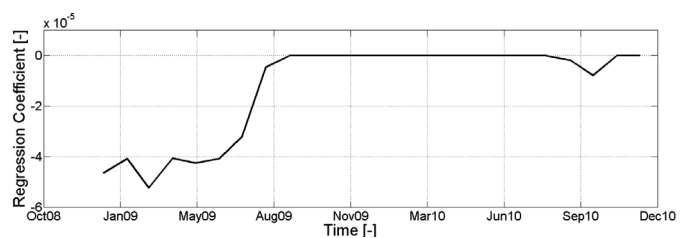


Fig. 4. Evolution of the reservoir level's coefficient

In the end, as the hydro-related variable selection results were unexpected, it is difficult to get any clear characteristics of what weather variables best explain the spot prices in a bottom-up model. A structurally meaningful result such as the selection at any time of the wind speed in Germany is not yet possible. The clear evolution in the selection of the reservoir level suggests that it might be too early in the

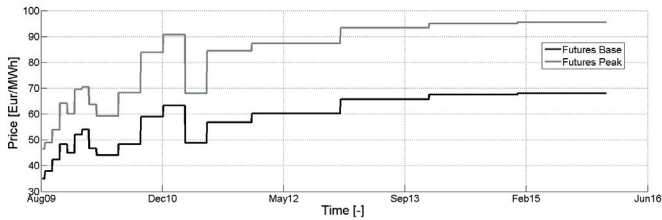


Fig. 5. The Implied Futures Curves of Germany (Ref. date: August 2009)

development of the liberalised Swiss energy market to sort the most relevant weather factors for building a robust HPFC. To analyse a market by variable selection results has also clear limits, for instance the bias induced by over-the-counter trading and the potential statistical anomalies. In our case, the Reservoir Level is a smooth, noise-free variable, so it can easily be misinterpreted by the regression technique to be an adjusting variable like in a Fourier analysis.

IV. BUILDING A HPFC WITHOUT FUTURES

The final step of the HPFC model consists of extending the implied Futures curve to an hourly basis (see Fig. 5). The hourly coefficients have been derived based on a combination of historical hourly profiles and simulated daily spot prices (see Fig. 1). In the following we propose to address the lack of implied Futures curve in the Swiss market with a simple mathematical solution based on the stylized fact that Switzerland is a major cross-border energy trader within Europe.

Due to its key location in the heart of Europe and limited congestion capacity between France and Italy, Switzerland is considered one of the main transit and exchange countries in the European power market. Figure 6 shows that Switzerland is of paramount importance to the European electricity market and serves as a transit country especially between France and Italy [18]. In addition, Switzerland is known as a peak-supplier in Europe due to its massive hydro-supply capacity. These qualitative facts can be usually pictured in the dependencies of the long-term contracts in the future and in the day-ahead market. As the Swiss market is short of a Future market, we propose to extrapolate Switzerland's economic partners' Futures to artificially form Swiss Futures with a spot-based relationship.

Since most of the trade with the Italian market is made over-the-counter and Austria is not relevant in terms of total volume exchanged, our focus is on the statistical importance of French and German markets on the Swiss market. The dependency of the Swiss spot price on the French and the German spot prices can be expressed as follows:

$$S_{CH} = b_{FR}S_{FR} + b_{DE}S_{DE} + b_0, \quad (3)$$

where S_{CH} represents the Swiss spot prices, S_{DE} the German spot prices, S_{FR} the French spot prices and b represents

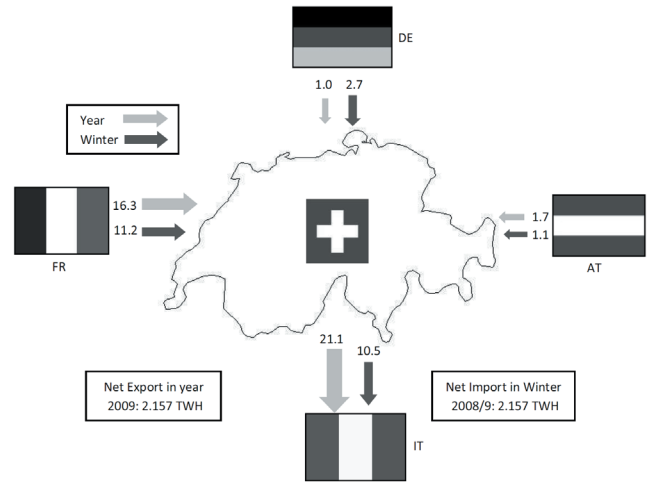


Fig. 6. Net import export statistics for Switzerland. Source: [18]

their respective regression coefficients. Since the French and German spot prices are highly correlated and exhibit heavy outliers, the lad-lasso regression technique is employed. Practically, the regression is performed for two different time windows: one is seasonal-oriented (100 days) and the other is long-term oriented (2 years of data). As we try to better understand the spot price dependencies, the regression is performed every 10 days from mid-2007 to end 2010 for the 100-days based window size and from 2009 to late 2010 for the 2 years window size. Fig 7 describes the outcomes of these regressions. Note that the training sets from one derivation to the next one are therefore highly overlapping.

The first graph displays the time evolution of the linear factors b_{FR} and b_{DE} for the two different time windows. As the 2-years based coefficients exhibit a high stability and provide a smooth curve, the 100-days based coefficients exhibit a clear yearly pattern on the range 2007-2008. This periodic behaviour is disturbed in the second half of 2009, following a major peak in the constant term, which suggests a market adjustment mechanism.

In all regressions performed, the t -statistic defined under the null hypothesis for coefficient i as

$$t_i = \frac{|b_i|}{\text{standard error}},$$

exhibit very high values, and are always above 3. Thus, despite high inter-correlation, both variables are always relevant for the regression. Based on this observation, the b coefficients obtained from the regression can be interpreted as a market influence indicator, making of this simple regression a market analysis tool. From this new point of view, it is a clear indication that from the fourth quarter of 2009, the Swiss spot price is becoming more influenced by the German spot price as compared to the French one. As it happens, in October 2009 the main electricity supplier in France, i.e. Electricité de France, announced that 30% of its nuclear power plants were scheduled for maintenance. This in combination with changes

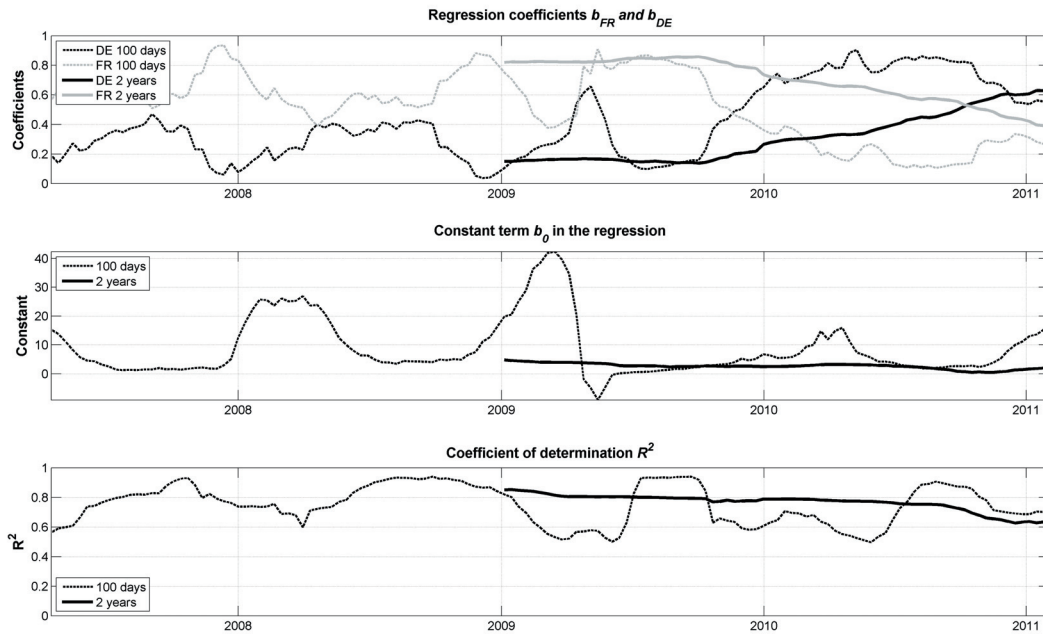


Fig. 7. Regression results for the Swiss spot price since inception using eq. (3) with two different time windows. The date axis indicates the last date of the training set. The 2-year time-series are necessarily shorter, due to increased data requirement. The corresponding t -statistic was larger than 3 in all cases.

in the national and international regulations, seems to have caused the dramatic change in the dependency of the Swiss spot price to the French and the German spot prices. In fact the dependency completely reverses, i.e. at the moment the Swiss spot price is more dependent on the German spot price than on the French one.

A second stylized fact is revealed when visualizing the level in the storage reservoirs in Switzerland as a function of time as it is done in Fig. 8. It can readily be observed that the reservoir level is highly periodic due to inflow of melting snow and precipitation and outflow of water to generate electricity. When the storage reservoirs are at their full capacity, i.e. in the third quarter, the coefficient of determination of the regression,

$$R^2 = 1 - \frac{\sum_i (y_i - \hat{y}_i)^2}{\sum_i (y_i - \bar{y})^2},$$

is consistently high. Note that as electricity spot price time-series are naturally highly correlated due to the daily, weekly and yearly patterns, the focus is put here on the evolution of the R^2 over time instead of the level itself. As an increase in R^2 qualitatively signifies an increase in the volume of electricity exchanged (import or export) and a high reservoir level means a local excess of energy supply capacity, the periodical increase in R^2 is consistent with the structural observations and corresponds to an intensive period of exportations.

From the foregoing it can be concluded that the simple regression proposed in Eq. 3 is consistent with the stylised fact of Switzerland as a main transit country. The dependency

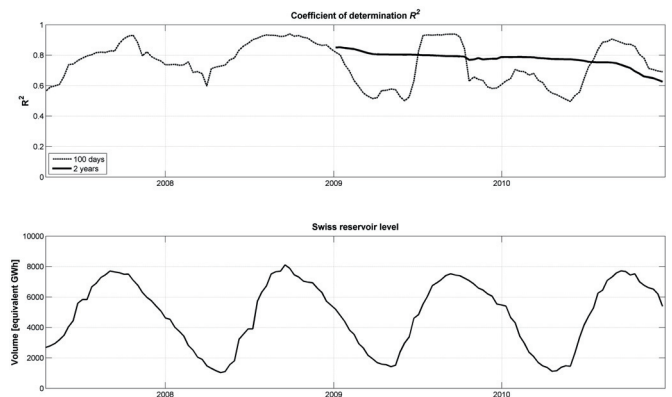


Fig. 8. The coefficient of determination compared with the Swiss storage reservoirs levels.

of the electricity spot price in Switzerland on the French and German spot prices is non-stationary and has in fact reversed over the last two years, matching with high precision the structural evolution and announcement of the market. While the 100-day coefficients provide information on the seasonal market evolution, the 2-year coefficients prove to be stable and reflect deep changes in the market structure. Assuming a no-arbitrage condition, the convergence property of the Futures towards the spot prices applies and we propose to build Swiss Futures by extending the German and French Futures with the long-term coefficients. As the French Futures have a lower granularity (3 monthly Futures instead of 7 for Germany) and

a shorter time range (3 years ahead at most for the French market whereas it is 6 years ahead at most for the German market), the combination of the two will provide an implied Futures curve with a mixed granularity and a 3 year look-ahead time-horizon.

V. DISCUSSION AND CONCLUSION

Energy deregulation in Switzerland is an ongoing process, with a number of major milestones to occur before the market can be considered mature. Not all of these have been examined in the current work. For example, nuclear power accounts for about 40% of the electricity production in Switzerland. A national referendum on the renewal and issuance of nuclear power plant permits will most likely take place in 2013 (perhaps even sooner given the rise in anti-nuclear sentiment associated with the earthquake-tsunami damage to the nuclear facility at Fukushima in Japan). The outcome of this hugely contentious vote will affect the structural make-up of the Swiss Energy market in a fundamental way. Rather than tackle every such possible scenario, our work has focused on how the methodical application of quantitative techniques can be used to systematically build an understanding of market conditions.

A simple HPFC model is presented and its implementation on the Swiss market provides the opportunity to better understand the drivers of the spot prices. Furthermore, we have presented a simple way to address the lack of Futures in the Swiss electricity market. The importance of the reservoirs level in Switzerland appears not to be reflected within spot prices. The rapid evolution of the market, the misleading sinus-shaped time-series of the reservoir level, the share of control energy and the over-the-counter trading, most important in Switzerland, are potential explanations. It is apparent that although the Swiss market represents a very small volume relatively to the French and German's markets, its key time-series follow their main market trends with immediate effect.

VI. ACKNOWLEDGEMENT

The authors are grateful to swissQuant Group for funding this work, and to Lukas Wehinger for his constructive review and discussion.

REFERENCES

- [1] Booz & Co., "A renaissance at risk: Threats and opportunities for swiss manufacturing," A Joint Study by the Swiss-American Chamber of Commerce and Booz & Co., Tech. Rep., 2010.
- [2] A. Gianfreda and L. Grossi, "Zonal price analysis of the Italian wholesale electricity market," in *Energy Market, 2009. EEM 2009. 6th International Conference on the European*. IEEE, 2009, pp. 1–6.
- [3] M. Madaleno, J. Pinho, and C. Ribeiro, "Some stylized facts in electricity markets: a European comparison," 2008.
- [4] M. Bierbrauer, C. Menn, S. Rachev, and S. Trueck, "Spot and derivative pricing in the EEX power market," *Journal of Banking & Finance*, vol. 31, no. 11, pp. 3462–3485, 2007.
- [5] D. Koekebakker, F. Benth *et al.*, "Modeling Term Structure Dynamics in the Nordic Electricity Swap Market," *The Energy Journal*, vol. 31, no. 2, pp. 53–86, 2010.
- [6] I. Simonsen, R. Weron, and B. Mo, "Structure and stylized facts of a deregulated power market," 2004.
- [7] A. Abdolkhalig, "Optimized Calculation of Hourly Price Forward Curve (HPFC)," *World Academy of Science, Engineering and Technology Int.*, vol. 45, pp. 134–144, 2008.
- [8] D. Dónáill and P. Conlon, "Developing a Risk Adjusted Pool Price in Irelands New Gross Mandatory Pool Electricity Market."
- [9] International Energy Agency, "Energy policies of IEA countries: Switzerland 2007 review," IEA Technical Report, Tech. Rep., 2007.
- [10] A. Tiberini and E. Amthauer, "Interconnections in central Europe and Switzerland," *Power Engineering Review, IEEE*, vol. 20, no. 4, pp. 24–25, 2002.
- [11] M. Filippini, J. Wild, and M. Kuenzle, "Scale and cost efficiency in the Swiss electricity distribution industry: evidence from a frontier cost approach," *Swiss Federal Institute of Technology*, 2001.
- [12] S. Fleten and J. Lemming, "Constructing forward price curves in electricity markets," *Energy Economics*, vol. 25, no. 5, pp. 409–424, 2003.
- [13] M. Hildmann and Co., "Robust Calculation and Parameter Estimation of the Hourly Price Forward Curve," in *Submitted to 17th Power Systems Computation Conference*. PSCC, 2011.
- [14] G. Caro, "Two empirical methods for forecasting spot prices and constructing price forward curves in the swiss power market," Master's thesis, ETH Zürich, 2010.
- [15] R. Tibshirani, "Regression shrinkage and selection via the lasso," *Journal of the Royal Statistical Society. Series B (Methodological)*, vol. 58, no. 1, pp. 267–288, 1996.
- [16] A. Tikhonov, "Solution of incorrectly formulated problems and the regularization method," in *Soviet Math. Dokl.*, vol. 4, no. 4, 1963, pp. 1035–1038.
- [17] H. Wang, G. Li, and G. Jiang, "Robust regression shrinkage and consistent variable selection through the lad-lasso," *Journal of Business and Economic Statistics*, vol. 25, no. 3, pp. 347–355, 2007.
- [18] Bundesamt Für Energie BFE, "Schweizerische Elektrizitätsstatistik 2009," Bundesamt für Energie BFE, Tech. Rep., 2009.