Minimizing Electricity Wholesale Risk using Tariff Design

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What is Wholesale Risk?

To supply electricity to customers an electricity supplier must determine:

- A half hourly demand forecast *f*.
- A half hourly cost of electricity *H*.

When forecast demand, *f*, does not equal actual demand, *a*, in a particular half hour the supplier must buy or sell from the Single Electricity Market. This creates an exposure to the supplier. It may gain or make a loss. This is called Wholesale Risk. More precisely in each half hour the following transactions occur:

$+aT$	The customer is billed for actual demand at Tariff price *T*.
$-fH$	The supplier pays for the forecast wholesale electricity.
$+(f-a)S$	Electricity is bought/sold to/from the Single Electricity Market at the System Marginal Price (*S*).

$$P = \sum_{i \in HalfHours} (a_i T_i - f_i H_i + (f_i - a_i) S_i)$$

Both *a* and *S* are stochastic since they are unknown at the time of setting the tariff. Thus *P* is a random variable and we define the wholesale risk as

$$Var(P)$$

Since there is a risk to offering electricity supply contracts suppliers will generally include risk premiums in their tariffs. This dissertation asks the question whether this risk can be reduced through better tariff design.

Objectives

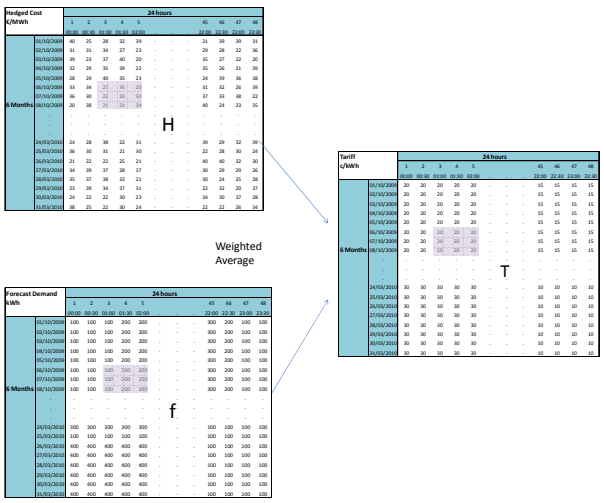
The principle research questions of the dissertation where:

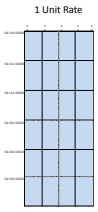
1. Can wholesale risk be reduced through the structure of a Time of Use tariff?
2. Can a Time of Use configuration be determined that minimizes wholesale risk?

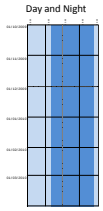
This leads to a number of ancillary objectives including:

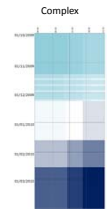
1. Developing an understanding of the search space consisting of all possible Time of Use configurations.
2. Understanding the consumption patterns of Irish residential electricity consumers.
3. Understanding the patterns prevalent in Irish wholesale electricity prices.

Defining a Tariff





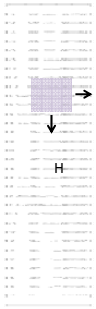




T is formed by taking a weighted average of *H* by *f* across different blocks of a partition of the half hours. Thus the partition defines the tariff and the Time of Use blocks. Some examples are shown on the right.

Approach

The wholesale risk is dependant on the hedged cost of electricity *H*. The contour plot on the right shows that *H* is highly non linear. If the partition of a tariff expands or contracts the effect on *Var(P)* will be non linear and *Var(P)* will not be convex.



An exact optimisation approach is therefore not appropriate and a meta heuristic is required.

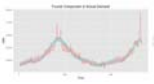
The approach taken was to combine a genetic algorithm with a simulation model. The simulation model acts as the fitness function of the genetic algorithm.

Genetic Algorithm and Simulation

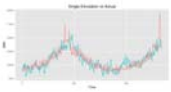
A genetic algorithm was developed using Python. A variable length representation of a tariff was used. To ensure the solution was tractable this incorporated parameterised constraints based on the results of a mathematical analysis of the space of all partitions. Crossover, mutation and initialization algorithms were all defined.

The simulation model was built around analysis of actual customer demand from the CER Smart Metering Trial and the historical outturn SMP. The analysis used the methods below.

Fourier Analysis



ARMA



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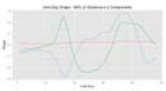
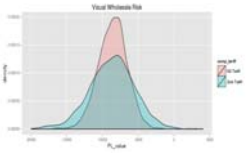


Results & Conclusions

Tariffs were found that reduce wholesale risk compared to simple tariffs in the context of the derived simulation models. Therefore from a proof of concept point of view the project proved successful. However the stochastic nature of the fitness function was able to mislead the genetic algorithm. In addition large model complexity did not allow complete trial and error of genetic algorithm parameters. A new fitness function focusing on the combination of wholesale risk and tariff complexity is suggested.



Acknowledgement

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