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**Conference Paper**

# Energy sector investment modeling under uncertainty for RA from the view of energy security

54th Congress of the European Regional Science Association: "Regional development & globalisation: Best practices", 26-29 August 2014, St. Petersburg, Russia

**Provided in Cooperation with:**
European Regional Science Association (ERSA)

# "Energy sector investment modeling under uncertainty for RA from the view of energy security".

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## Introduction

The Armenian economy has been growing strongly in recent years. The country has successfully implemented a comprehensive stabilisation and a structural reform program in energy sector. Although now Armenia almost completely depends on imported energy. The most domestically produced primary energy is electricity from hydroelectric plants and one nuclear power plant. However, there are serious challenges:

a. Sufficient electricity service

b. Energy safety

c. Maintenance of electricity service availability for consumers at the same time providing the financial vitality of the sphere.

In 2000-2030 the demand of the investments in the electricity sphere is estimated about 9.8 trillion dollar in the world. The developing countries need more than the half of these investments. The speed, the succession, the volume and the results of the results of the reformations differ from each other in different countries.

The investor considering a potential project faces two investment problems; if or when to invest and the optimal capacity choice. This decision is very important because of its irreversibility. Once a plant has been constructed it has little alternative use, as the different components often are tailor-made. The investment will for all practical purposes be a sunk cost. Expanding the plant is also very expensive. This means that it is very important to make the correct investment decision; choosing the optimal investment time and the optimal plant size.

Uncertainty factor occurs when a decision may bring not one, but several effects. Uncertainties in electricity industry are connected with.

- Primary energy market prices
- Electricity prices
- Demand grow
- Technology development
- Regulation and political uncertainties

With uncertainty and irreversibility, McDonald and Siegel (1986) and Dixit and Pindyck (1994) have shown that real options analysis leads to better investment decisions than traditional net present value analysis when the investor has the opportunity to postpone his investment. Their investment timing model must be expanded when the investor must are given additional choices in the design of the project, such as the production capacity. Dias, Rocha and Teixeira (2003) and Décamps, Mariotti and Villeneuve (2006) consider the choice between several capacities (projects) and show that the introduction of more choices may lead the investor to wait more - to see which of the capacity (project) choices will turn out to be optimal. Fleten, Maribu and Wangensteen (2005) build on those models to analyse the choice between known discrete capacities for small-scale renewable power plants. In the McDonald and Siegel (1986) model there is a triggering level of the project value or output price at which it is optimal to invest.

The goal of our research is to find out the possible ways for the provision of energy security. We have used econometric models assessment and real options method. We have assessed VAR models and simultaneous equations systems.
We have studied the following relations:

- **The analysis of the electricity production and investments trough VAR model.**
- **The analysis of interdependence between electricity and natural gas consumption from the point of view energy security.**
- **The impact of investments on the electricity demand under uncertainty.**
- **Cost comparison for the electricity demand satisfy with real options method.**
- **Investment decision making for small hydropower projects with real options method for RA.**

**Method**

Nowadays, as a new tool the real options theory has wide usage for capital planning and assets estimating (Dixit and Pindyck (1994), McDonald and Siegel(1986) ).By means of the real options the analysis allow us to decide the flexibility of the investment possibility both in fulfilling and postponing investments.

*The real option is a right, not a duty with some expense to realise a concrete period activity.*

The real option estimation may be viewed as investment optimization problem in uncertainty. The idea is the following: to maximize the net present value of the actives comparing suitable alternatives.

Dynamic planning and contingent claims methods are used to solve the real options optimization problem: in our research we used the second approach and the essence of which is in the following:

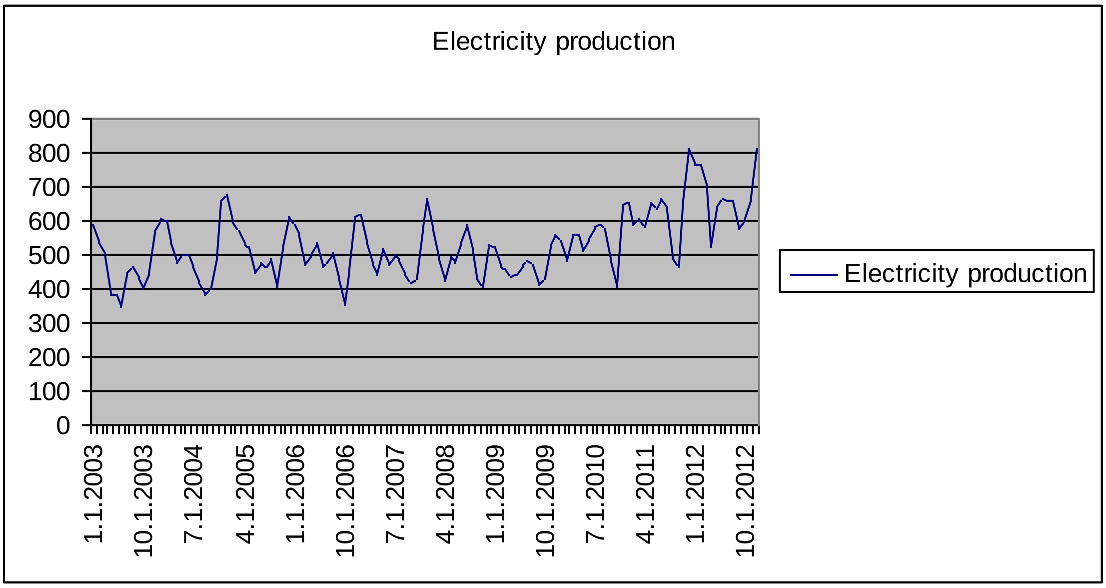
Contingent claims method is based on financial economy not on arbitration theory. There is an arbitration alternative which allows buying cheaper actives and selling the more expensive ones. In the actives pricing theory not arbitration situations claim the risks connected with situation alternation to be postponed due to the selling actives. In this case estimating the project cost must be cooperated optimally. If not so, you should wait for more profitable price again.

The real options analysis are usable in energy sphere as the latter is described by long term and not returnable investments since we can lose that possibility by not doing investment at that very moment when there are uncertainties connected with produced, distributed and consumed energy.

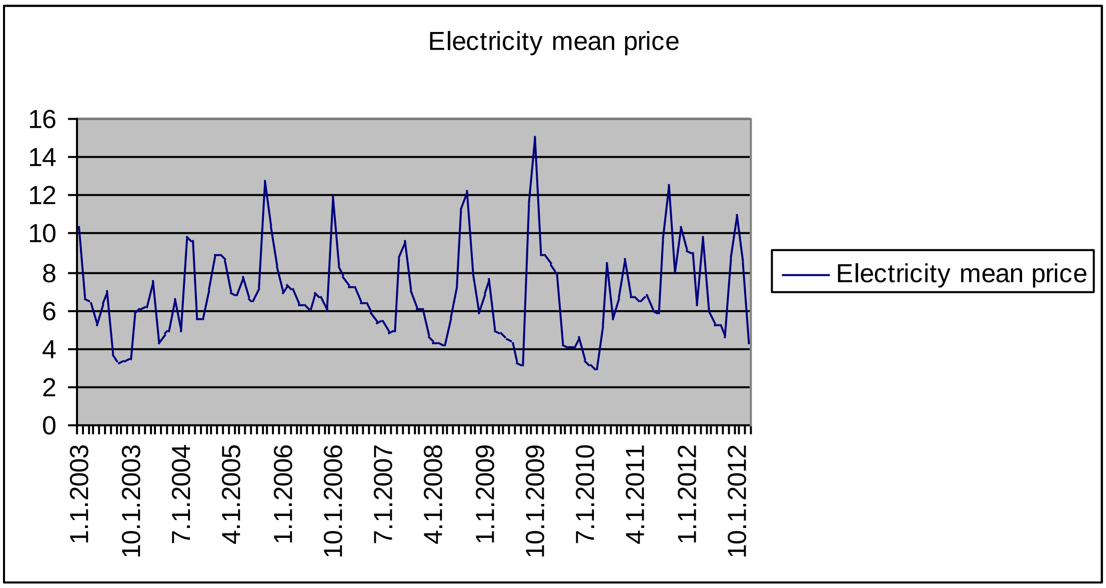
We have the following optional possibilities while doing investments especially in electro energy sphere: waiting, expending or increasing the investment value in the station as well as choosing between different technologies.

**Data analysis**

The indexes in our research have the following dynamics during the observed period**:**

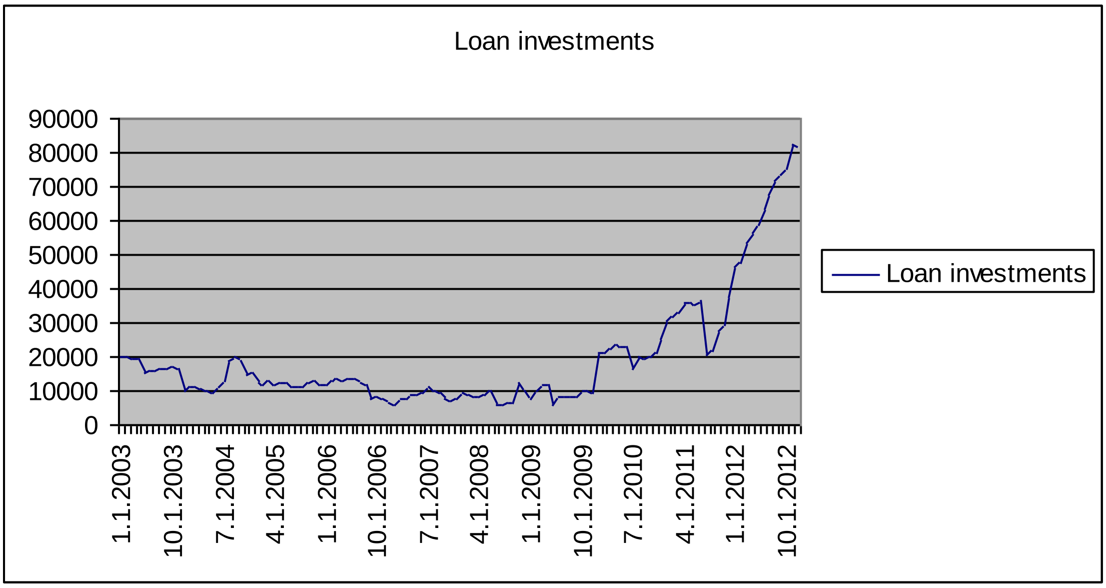



Electricity monthly production in the observed period is described seasonally which is especially explained by the demand difference in winter and summer months.




One of the main factors of electricity industry is to set electricity sail tariff by stations.

Generally, electricity average tariff behavior may be separated into the following groups: [2003-2005], [2006-2008], [2009-2010] և [2011-2012]. In the first period the increase of the tariff is conditioned by the existing expenses for the reformations in the energy sphere of Armenia. In the second period cheap costly resources has great weight in the production. In the third period the situation is not definite. In 2010 the gas price fell down to 325 US dollar in the result of the international financial crisis, but then it began increasing. For the last period the decreasing tendency is explained by the following: in 2011 Yerevan combined steam cycle power station with 250 Mw power was used in Yerevan TPP.



Taking into account the investment information limitation we have used credit investment data in 2003-2023 given to energy sphere to modify a mutual dependence between electricity production and investment.

We can note, that credit investments present stationary series till 2009, after gradual and then abrupt increase is conditioned by the fulfilling of the great investment projects, for example, Meghry hydropower plant about 130 Mw power and about 800 million kvth electricity production yearly on the river Araks . The whole electricity produced here will be exported to Iran. The investment projects done for the territory integration have significant role.

What concerns state investments, then their meaning based on the calculations done in our research is not important because of the following: the outer investments to energy sector under the state guarantee go into the state budget and are checked out with the same quantity in the cost part. Hence, the investments done by the state budget include credits but the credits further repayment is done through the tariff. On the other hand the state expenses in the electro energy sphere are considered to be rather small part of the state budget: in 2003 it was only 3,6 % of the total cost, and in 2013 it was 0,5%.

**Econmetric models**

We have assessed the following econometric models, which have sufficient significance levels:

A.

LNPROD = 0.82*LNPROD(-1) -0.4*LNPROD(-2) + 0.12*LNINVEST(-1) -0.03*LNINVEST(-2) +2.83,

LNINVEST=0.07*LNPROD(-1)+0.17*LNPROD(-2)+0.87*LNINVEST(-1) +0.09*LNINVEST(-2)-1.1,

Here our data are monthly. The model results show the significance dynamic relation for one and two lags influence in the first equation. And we have influence on the investments only for previous lag on the second equation. These relations are marked with the fact that the investments don’t concern straight expansion of the production facilities, but the increase of the energy supply reliability and safety. The most part of investments have been taken for solving technical problems during observed years. In this case not typical factors can also be important (loan or exchange rates).

B. Next problem is about electricity and natural gas population consumption. We have assessed the following VAR model.

ENPOP = 0.83*ENPOP(-1)-0.2*ENPOP(-2)+0.39*GAZPOP(-1)+0.46*GAZPOP(-2)+ 52.24,
GAZPOP=0.29*ENPOP(-1)-0.27*ENPOP(-2)+1.12*GAZPOP(-1)-0.45* GAZPOP (-2)+ 11.7

There is a dynamic relation between electricity and natural gas population consumption for one and two lags influence in RA. Moreover, the first lag influence is positive, the second one is negative. The reaction of population for the electricity consumption of the last month(0.83) is much more than the natural gas consumption (0.46) two months ago. It means that it is easier to make changes in the electricity production process than to imported natural gas. The first lag positive influence can be explained by the tariff 's construction which doesn't reflect the differences between costs of winter and summer electricity production. All in all, it can be difficult enough to make decision per one or two months for population. Here it is important the human behavior too. In the result it will be possible to choose between the alternatives of electricity and natural gas consumption. Hence, we have some opportunities to increase energy security safety.

Energy safety and effectiveness actions will influence the decrease of imported fuel dependence due to the usage the renewable resources. The investments involvement in the hydro resource usage can at least promote the demand satisfaction with cheaper production costs. For this, we have assessed the following simultaneous equations system:

We have come to an important result : when doing investments at the same time it is possible both to decrease gas consumption and increase electricity consumption. Such influence may give opportunity to replace natural gas consumption with electricity consumption.

C. The impact of investments on the total electricity demand is important as there are correlation equal to 0.95 for yearly dates. Here we can use this model for 2-3 years prediction. We have AR(1) autoregressive stochastic process for demand, which allow to observe the problem under uncertainty and compare necessary investments with real options method

Demand=4217.45 + 0.86 * Demand (-1) (1)

Then we have got the best result with linear model for investments and total production :

Invest = -184462 + 102.32 * Product (2)

Taking into account the fact that electricity can not be reserved (the produced amount is consumpted), we predicted demand for 2013 and 2017 years with (1) equation . Then the investments have been accounted with (2) equation and discounted for 2012 year, which are

70109.03 million AMD and 60465.86 million AMD accordingly. Discounting has been done using variation in AR(1), which is based on real options method .

Hence we can assess necessary investments for electricity demand satisfaction under uncertainty using real options method for Armenian energy sector and compare production facilities.

D. Taking into account a number of risky factors influence on energy security safety we have studied electricity demand gap under uncertainty and compared the necessary costs for hydro and thermal resources . For using real options method we have these stochastic processes:

$$Hydro\_cost(t) = 2133 - 117.26 * Meanpr(t) + 0.69 * Hydro\_cost(t-1), \quad R^2 = 0.65$$

$$Therm\_cost(t) = -384.27 + 314.17 * Meanpr(t) + Therm\_cost(t-1) * 0.75, \quad R^2 = 0.83$$

We see that also increase in mean price will decrease hydro costs and increase thermal costs , hence it is effective to do investments costs in hydro resources ‘ facilities expansion. Then we have used growth rates from these exponential equations:

$$Hydro\_cost= 352.49 * e^{0.003* Hydro\_prod}$$

$$Therm\_cost = 265.68 * e^{0.005* Therm\_prod}$$

We have discounted the investments by these versions taking 5.8 % discount rate:

a) taking into account total cost growth rates and variation: $\alpha_{hydro}= 0.69$ and $\sigma_{hydro}= 244.5$, when $R^2 = 0.65$, but $\alpha_{therm}= 0.75$ and $\sigma_{therm}= 480.7$, when $R^2 = 0.8$

b) taking into account total cost and production providing growth rates and variation: $\alpha_{hydro}= 0.003$ and $\sigma_{hydro}= 0$, when $R^2 = 0.57$, but $\alpha_{therm}= 0.005$ and $\sigma_{therm}= 0.001$, when $R^2 = 0.35$. In this case the influence is almost insignificance.

c) taking into account the demand growth rates and variation by hydro and thermal plants: $\alpha_{hydro}= 0.003$ and $\sigma_{hydro}= 0$, when $R^2 = 0.78$, but $\alpha_{therm}= 0.73$ and $\sigma_{therm}= 63.5$, when $R^2 = 0.52$.

In the result of the first and third variants assessment and comparison the costs by hydro and thermal plants we showed that usage the hydro resources is less costly. Hence, we are assured once more that it is necessary to make favorable conditions for the development of renewable energy promoting and decrease of natural gas import.

E. To support investors in energy sector of RA we have assessed small hydropower investments projects with real options method. In our research we have AR(1) process for marginal revenue:

MARJAS = 4,4596881 + 0,6022672 * MARJAS(-1)

Then we use the following relations:

$INVEST=26,806616 * e^{0,000766*PRODPRIV}$

$TMARJA = 3,381269*e^{0.004048*t}$

Using growth rates and coefficients in these models investor can decide the best time and production volume for small hydropower projects. It must be done through real options method which help to find the trigger level for electricity price and revenue. If the current trading price is less than trigger level it will be profitable to postpone the investment.

We have got that current marginal revenue is more than the trigger level. This means that it is profitable to invest in small hydropower projects in Armenia.

Under uncertainty it is important for investment decision making marginal revenue's variation. There is a correlation between marginal revenue and variation for Pearson coefficient equal to 0.659. We have done sensitivity analyses with the following linear regression too:

MARJAS = 4.302 + 0.831*σ , $R^2$ =0.5

It is clear that greater uncertainty brings to greater marginal revenue. In the result the investment present value becomes greater too.

So we have presented a method for investors, which will allow them to take into consideration few risky situations under uncertainty and to avoid not profitable investments.

**As the mentioned survey conclusion we can say:**

a) The most part of investments have been taken for solving technical problems during observed years. It promoted to improve energy supply reliability and safety: especially, the electricity wastes in high voltage networks had been 4.2% and 21.7% in distribution networks in 2003, but 1.9% and 13.6% accordingly in 2012.

b) Doing investments it is possible to give opportunity to population for replacing natural gas consumption with electricity consumption and increase energy independence.

c) Real options method can be used in Armenian energy sector investments assessment, which will allow take into account risky situations and other uncertainties.

d) The satisfaction of electricity demand gap with hydro production is less costly then thermal production in Armenia.

e) We have found that investment and regulation area for small hydropower producers in Armenia are quite favorable.

The results that we have got can be used in the short-term development plans for Ministry of Energy and Natural Resourses and in the strategic planning processes for Public Services Regulatory Commision of the RA.

Our research has been done in macro level with some simplifications, but it is possible to expand the research in micro level. Though the information for calculations is yet inaccessible to do some conclusions.

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