Price convergence in the Central American regional electricity market

Walter Cont, Diego Barril and Agustín Carbó*

Abstract

After 7 years since the formalization of the regional electricity market (MER, according to the Spanish acronym) in Central America, operating in a parallel fashion with domestic markets, we study the evolution of spot prices to understand whether the MER allowed for price convergence in the transactions that took place among countries. We use a test proposed by Phillips and Sul (Econometrica, 2007) to run the convergence test and find that long term forces are in effect, interrupted temporarily in mid-2016 after the introduction of a hydroelectric plant (Reventazon) in Costa Rica. This convergence result is accompanied by indirect evidence of a reduction in the level of spot prices during the period (after having considered the cost of fuels or natural gas).

Resumen ejecutivo

Luego de 7 años desde la formalización del Mercado Eléctrico Regional (MER) en Centroamérica, este paper estudia la evolución de los precios spot para entender si se produjo una convergencia entre los países que forman parte del MER. Utilizando una prueba propuesta por Phillips y Sul (Econometrica, 2007) para ejecutar el test de convergencia, se puede concluir que las fuerzas de largo plazo hacia un precio único han operado, habiendo sufrido una interrupción temporal a mediados de 2016 después de la introducción de una planta hidroeléctrica (Reventazón) en Costa Rica. Este resultado de convergencia va acompañado de evidencia indirecta de una reducción en el nivel de precios spot durante el período (después de haber considerado el costo de los combustibles o del gas natural).

JEL Codes: Q40, Q48, N73.

Keywords: Electricity prices, price convergence, SIEPAC, Regional Electricity Market.

---

* Walter Cont (corresponding author): CAF – Banco de Desarrollo de América Latina and Universidad Nacional de La Plata. Contact information: wcont@caf.com

Diego Barril: CAF – Banco de Desarrollo de América Latina. Contact information: dbarril@caf.com

Agustín Carbó: IAE – Universidad Austral. Contact information: acarbo@austral.edu.ar

This paper is part of a research project “CAF (2021). RED 2021: Caminos para la integración, facilitación del comercio, infraestructuras y cadenas de valor.”

Price convergence in the Central American regional electricity market

1. Introduction

Electricity integration is motivated by the advantages offered by the interconnection among partner countries and the multiple benefits implied by it. Most common benefits are the possibility of achieving economies of scale in production and the consequent reduction in costs, improving the security of supply, reducing the impact of unforeseen shocks and achieving better results in terms of service quality and protection of the environment. All of this has a positive impact on consumers and firms. Integration processes can range from an interconnection of electricity systems to broad integration, and usually involve agreements, such as bilateral or multilateral treaties, depending on the countries that are involved in the integration process.

A special case in Latin America is the Regional Electricity Market created in the Central America region. This has been the most far-reaching experience in the sector, followed by a cumulus of bilateral initiatives in South America. The experience has been well documented in Echevarria et al. (2017), including several measures of simulated benefits. However, the experience still lags behind of a profound market integration, as the one that took place in Europe (see Pollit, 2019, and Batalla-Bejerano et al., 2019).

This paper studies a specific effect, which is the convergence of spot prices, and alongside, provides some evidence on the reduction of costs. Price convergence is relevant for markets to work. This issue has been deeply studied in many markets throughout continents. We follow the methodology to test convergence proposed by Philips and Sul (2007, 2009), which has already been recently applied to the energy sector. The main result is that the spot prices tend to converge between mid-2013 and mid-2016, when there is a disruption by the introduction of a hydro plant in Costa Rica. A second phase take place in which prices converge again, this time at a stronger pace. This result is accompanied with partial evidence of a reduction in prices, consistently with a situation of less reliance on contaminant hydrocarbons.

This study relates fits the strand of literature on price convergence in electricity markets. A long list of papers analyzed convergence of electricity spot prices in the European market throughout the formation of the common market, identifying patterns between peak/off-peak (Zachmann, 2008), geographical distance and grid interconnection (de Menezes and Houllier, 2016), interconnection of neighboring countries (Kalantzis and Milonas, 2010). Also other papers focus on the relevance of the price of fuel mix on electricity prices (de Menezes and Houllier, 2016), external shocks such as the volatility of oil price on the bias to produce with local sources (Kalantzis and Milonas, 2010), and the cointegration between electricity and natural gas markets (Bosco et al., 2010). A recent work by Ciferri et al. (2020) finds that country-specific price dynamics converge toward a steady state path, although exogenous shocks have permanent effects. They also find several cases of unidirectional causality in prices when comparing pairs of countries.

Apergis et al. (2016) analyzes the Australian case, concentrate on the phenomenon of price convergence and the time it takes for regional prices to converge, after the establishment of a national domestic network which connected five regional markets, complementing or improving methodologies and results from previous research (Dempster et al., 2008, in California-US, Nepal and Foster, 2013, in Australia). Our work closely relates to this paper.

There is also significant research on the natural gas market. For example, King and Cuc (1996) study price convergence across various natural gas basins within US and finds that converged increased significantly after deregulation of the gas market in the mid-80s, in favor of more integration among regional markets. Growitsch et al. (2015) study the deregulations that took place in Germany in 2007 and their effects on price convergence of natural gas, both internally and with the Dutch market and find that prices converge to a reasonable degree but that there may be some capacity constraints responsible of some unexplained price differentials. Li et al. (2014) compare the integration of natural gas markets in North America, Europe and Asia. Finally, Ma and Oxley (2012) analyze regional convergence of energy markets in China.

The paper organizes as follows. Section 2 describes de regional electricity market project. Section 3 presents the methodology to analyze price convergence. Section 4 presents the main results. Finally, Section 5 concludes.

2. Regional Electricity Market in Central America: market creation, regulation and challenges

The most far-reaching integration process in Latin America takes place in Central America, connecting 6 countries (Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica and Panama) to optimize energy reserves and take advantage of the energy matrix diversity. Interconnections started by pair of countries in 1975. In 1996 the regional integration process gained momentum with the signing of the Central American Electricity Market Framework Treaty. The agreement, and its two protocols, created the regional bodies for the operation and regulation of the Regional Electricity Market (*Mercado Eléctrico Regional*, MER): the Regional Operating Entity (*Ente Operador Regional*, EOR), the regional regulator called the Regional Electric Interconnection Commission (*Comisión Regional de Interconexión Eléctrica*, CRIE) and the Director Council of MER (*Consejo Director del Mercado Eléctrico Regional*, CDMER) in charge of the energy integration policy. The Grid Owning Company (*Empresa Propietaria de la Red*, EPR), owned by member companies and other partners, developed the first regional interconnection system (SIEPAC) which connects the six national systems with a transmission capacity of 300 MW.

Regional integration was achieved through the creation of the Regional Electric Market (MER) and the construction of the SIEPAC project. The MER started operations in 2002 on a temporary basis until the MER regulation (RMER) came into effect in 2013. Since then, MER works in parallel with the six national systems, some of them characterized by vertically integrated monopolies coexisting with limited participation from private generation (Costa Rica and Honduras) and others characterized by market systems (El Salvador, Guatemala, Panama and Nicaragua). However, operation and administration of the system as well as regional transactions in MER are governed by their own rules, forbidding the pass through of domestic subsidies or taxes to other countries.

In this context, countries have adopted harmonization measures between their national and supranational regulations. Electricity transactions in MER can be either spot (with a system of nodal prices, which reflect the short-term opportunity costs for an injection or withdrawal, including losses and congestion) or contract based among market agents. The operator also provides auxiliary and operating services of the MER as well as regional transmission services.

As MER developments began taking shape, partner countries faced several kinds of challenges that affect MER's resilience to external events. For instance, during the period of the increase in the price of oil (started in 2004), Honduras and El Salvador (net importers) decreased their exchanges and engaged in price controls within their domestic markets. Another concern in the MER framework is the effective use of capacity, and its implications for planning the expansion of the regional transmission system. Although there is a nominal capacity of 300 MW, for different reasons some countries use it below its potential (see, for example, the limitations imposed by the operator of the Panama system – effective capacity between 50 and 15 MW – to prevent the misfunction of the Fortuna Hydroelectric Power Plant in simple contingencies, as explained by EOR, 2021). In turn, EOR plans the expansion of the grid and coordinates with national systems towards the necessary national reinforcements, but such coordination has been limited. Related to this, it is expected generation programmed to a regional scale, but so far only generation capacity has been expanded at the national level. Nowadays, long-term contract transactions did not fully develop yet. Even though RMER foster transactions under firm conditions, national regulations have prioritized national shortages and only contracts no longer than 1 year have been the common practice. These issues are the object of analysis in the agenda of the Third Protocol to the Treaty (see details Echevarría et al., 2017, CDMER, 2015 and 2020, and Mercados - Aries Internacional, 2021).

There have been work documenting the potential gains of the expansion of electricity trade throughout Central America. The standard practice is simulation of direct benefits accrued by consumers, producers and shareholders and indirect benefits from efficiency gains that spread out through local economies. All of them coincide in that the SIEPAC project has been beneficial for the region, but the benefits do not spread out homogeneously (and in some simulations, individual partners may even lose).[1,2] Our paper complements this work by reporting other set of results, mainly on price convergence and some evidence of cost reduction.

[1] See CDMER (2020). Echevarría et al. (2017), Levy Ferre et al. (2020). A similar methodology is applied, for example, to assess benefits of regional electricity trade in South Asia (Timilsina and Toman, 2016).

[2] In the case of European electricity market, Pollit (2019) reviews the evolution of cross-border markets throughout the process of creation of a single regional markets and states that net benefits (on prices, costs,

3. Methodology for the convergence analysis

To assess convergence in a panel structure, Phillips and Sul (2007) develop a semi-parametric test and an algorithm for the formation of clusters. Under the convergence hypothesis the difference between the countries' prices must tend to zero when *t* (time) tends to infinity. In addition, the fact that the difference between countries is decreasing over time is not a sufficient condition to guarantee global convergence. The authors raise the possibility of convergence by subgroups and divergence in general terms. In order to differentiate both scenarios, the authors develop a test based on a simple time series regression, in which one parameter (α) is introduced into de convergence hypothesis. This methodology not only allows the general convergence analysis, but also, in the divergence scenarios there is the possibility of analyzing the convergence in clubs (subgroups of countries). Furthermore, as Phillips and Sul (2009) do, the transition can be studied at different times, analyzing the convergence in different sub-periods of time.

Specifically, the methodology starts from the following equation where p_{it} represents spot price declared in MER by country *i* in time *t*. There are six countries (*i=1,…,6*). Following Phillips and Sul (2007, 2009) we assume that prices can be decomposed into a common component μ_t and an idiosyncratic component λ_{it}:

$$p_{it} = \lambda_{it}\mu_t \qquad (1)$$

The idiosyncratic component also varies over time and captures the deviation with respect to μ_t. Within this framework, convergence would mean:

$$\lim_{k\to\infty} \lambda_{it+k} = \lambda\,, \quad \forall i \qquad (2)$$

Since equation (1) cannot be studied directly, Phillips and Sul (2007) eliminate the common component (μ_t) by rescaling p_{it}:

$$h_{it} = \frac{p_{it}}{(\sum_{i=1}^{6} p_{it})/6} = \frac{\lambda_{it}}{(\sum_{i=1}^{6} \lambda_{it})/6} \qquad (3)$$

Now h_{it} is a relative measure that captures the transition path with respect to the panel average. In order to run the convergence test, define:

$$\lambda_{it} = \lambda_i + \sigma_{it}\,\varepsilon_{it} \qquad (4)$$

where λ_i is fixed (through time), ε_{it} is iid (0,1) with respect to *i* but may be slightly dependent over time, and σ_{it} is defined as follows:

$$\sigma_{it} = \frac{\sigma_i}{L(t).t^{\alpha}},\ \sigma_i > 0,\ t \geq 0$$

and GDP) may have been small, as the creation of a single electricity market was fostered in parallel to policies that subsidized renewable generation.

The function $L(t)$ is growing in t and diverges as t approaches infinity (later on, we use the function $L(t) = \log(t)$). The parameter α determines whether t^{α} approaches to 0 ($\alpha < 0$) or infinity ($\alpha \geq 0$). Therefore, λ_{it} in equation (4) converges to λ_i for $\alpha \geq 0$. If $\alpha \geq 0$ and $\lambda_i = \lambda_j = \lambda$, for $i \neq j$, prices converge.[3]

The null hypothesis of price convergence for all countries is

$$H_0: \lambda_{it} = \lambda \; and \; \alpha \geq 0$$

and the alternative hypothesis of price convergence for some country i is[4]

$$H_1: \lambda_{it} \neq \lambda \; or \; \alpha < 0$$

According to Phillips and Sul (2007, 2009), the test focuses on examining the sign of α. The way to test the null hypothesis is based on the following regression:

$$\log\left(\frac{H_1}{H_t}\right) - 2\log L(t) = \hat{c} + b\log t + \widehat{u_t} \qquad (5)$$

where H_t is the square of the relative distance between coefficients, i.e.,

$$H_t = \frac{1}{6}\sum_{i=1}^{6}(h_{it} - 1)^2 \qquad (6)$$

Regression (5) is estimated for t = [rT], [rT} +1, …, T in which r is a value between 0.2 and 0.3 (dropping this way between 20 percent and 30 percent of the initial data). We estimate autocorrelation and heteroscedasticity consistent robust standard errors for coefficients. Since $b = 2\hat{\alpha}$, the null hypothesis is $b \geq 0$ (against $b < 0$). The t-value, for a one-tailed test, less than -1.65 rejects the null hypothesis of convergence (using a 5 percent significance level). The magnitude of a positive b coefficient measures the speed of convergence (Phillips and Sul, 2009).

The data set was built based on daily prices reported by EOR (regional operator entity) from June 2013 to March 2021. Ex ante spot prices are reported on daily basis, per node. They are averaged by nodes corresponding to a certain country to arrive to prices by country. Following Phillips and Sul (2007, 2009) recommendations we apply a Hodrick-Prescott filter to work with the series trends. Given the characteristics of the sector, we used daily prices to perform the convergence analysis. An alternative configuration with weekly prices (to avoid daily volatility) provides the same results.

We study spot prices because we believe that they are a better proxy of short run marginal cost than domestic marginal cost values. The latter may be biased by domestic policies (subsidies, local regulation and policies, and market configuration). MER regulations clearly state that subsidies or

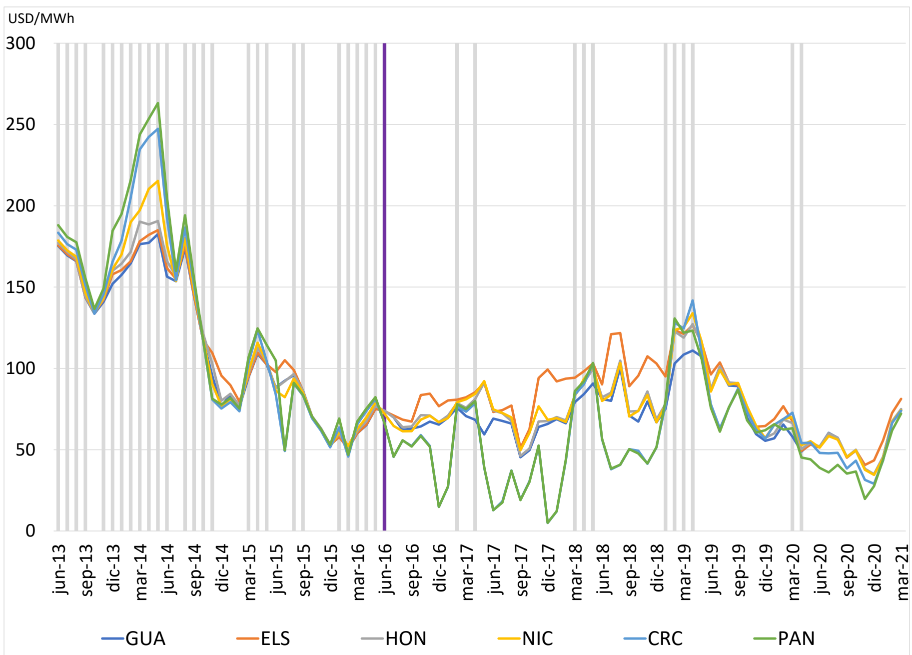
[3] Additional heterogeneity can be introduced in $L^i(t)$ and α^i, but as long as $L^i(t).\alpha^i$diverge, the long-term result holds.

[4] It is possible that $\alpha \geq 0$, but and $\lambda_i = \lambda_j = \lambda_A$ and $\lambda_k = \lambda_l = \lambda_B$ for subsets of partners (i.e., group convergence; in this example, into groups A and B). Given the final result of our paper, we do not pursue this line of research.

other forms of interventions cannot be passed through transactions that take place in the regional market.

Figure 1 shows the six time-series on spot prices on a monthly frequency. Although we use daily and weekly data to run the tests, the monthly data shows that prices tend to converge towards mid-2016, then they are shocked (mainly Costa Rica and Panama depart from the group, with lower prices, for more than two years), and finally they evolve within close range -converge- again. Also, the level of prices decreases strongly between 2014 and 2015 following international fuel prices. Later, we provide some partial evidence that this is not the only factor in the reduction of spot prices.

Figure 1 – National spot electricity prices in MER (ex-ante), in USD per MWh



Source: own elaboration based on data published by EOR (https://www.enteoperador.org/mer/gestion-comercial/informes-de-transaccion-diario-mensual-y-anual/#elf_l1_Lw). GUA: Guatemala, ELS: El Salvador, HON: Honduras, NIC: Nicaragua, CRC: Costa Rica, PAN: Panama). The gray bars show the months in which Costa Rica generated electricity with natural gas (at the margin).

Table 1 summarizes the main statistics. Overall, three countries show average prices over USD 90/MWh (El Salvador, Honduras and Nicaragua), while the other three countries show prices below that value (Panama, Costa Rica and Honduras). It is interesting that cases such as Costa Rica and Panama had highest prices during 2013-2016, but then showed the lowest prices in 2016-2021. In good hydrologic conditions, Guatemala, Costa Rica and Panama can achieve prices below USD 10/MWh. Finally, both Figure 1 and Table 1 a strong decrease in prices (taking the chosen sub-periods as reference, a decrease over USD 50/MWh).

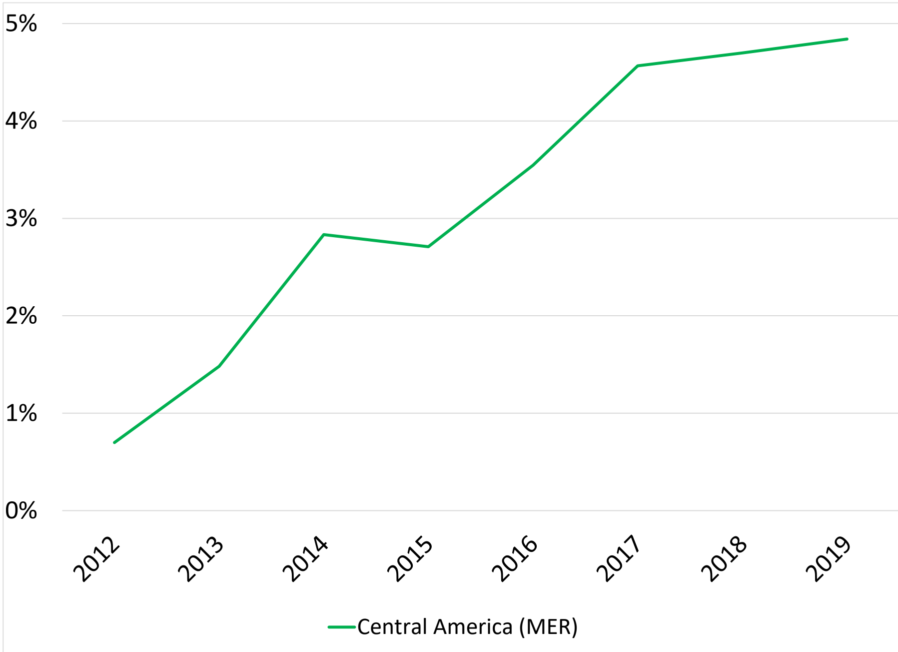
Figure 2 shows the evolution of aggregate trade between 2010 and 2019. Energy trade has been persistently increasing since the formalization of MER (although there have been specific bilateral trades before then), so the disruptions in spot prices between mid-2016 and the second part of 2018 do not seem to be due to a lack of trade.

Table 1. Average daily electricity spot prices in MER (USD/MWh)

	Guatemala	El Salvador	Honduras	Nicaragua	Costa Rica	Panama
2013-06-01 to 2021-03-13						
Mean	87,65	95,87	91,37	92,32	83,89	84,82
Std.Dev.	39,19	37,92	40,69	43,23	55,41	59,19
Max	200,68	204,16	207,85	234,17	268,63	302,04
Min	2,61	17,00	16,64	16,28	0,85	0,87
Observations	2820	2820	2820	2820	2820	2820
2013-06-01 to 2016-06-02						
Mean	116,13	118,93	119,44	121,09	124,91	130,31
Std.Dev.	44,65	44,57	46,91	51,33	60,57	64,75
Max	200,68	204,16	207,85	234,17	268,63	302,04
Min	27,62	39,83	27,62	26,50	19,94	20,36
Observations	1097	1097	1097	1097	1097	1097
2016-06-02 to 2021-03-13						
Mean	69,54	81,20	73,52	74,02	57,80	55,89
Std.Dev.	20,15	23,21	22,23	22,91	30,78	30,33
Max	135,01	143,87	146,57	148,25	158,03	157,58
Min	2,61	17,00	16,64	16,28	0,85	0,87
Observations	1724	1724	1724	1724	1724	1724

Source: see Figure 1. The summary statistics are run with raw spot prices, before applying the HP filter.

Figure 2 – Ratio of aggregate imports over electricity consumption: 2010-2019



Source: own elaboration based on data published by MER and in national energy balances. Total of imports over total of consumption in six countries (Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Panama). Guatemala imports electricity also from Mexico, but this inclusion does not distort the results shown in the graph.

4. Results

Modeling the economic transitions has always been relevant in international trade and growth literature (see Phillips and Sul, 2007, 2009). As stated in the introduction, empirical studies in the energy sector can be found in Growitsch et al. (2013) for price convergence and efficiency in German natural gas markets, King and Cuc (1996) for convergence in North American spot markets and Apergis et al (2016) for convergence in electricity markets in Australia, among others.

Table 2 shows the convergence test on spot prices in the context of the commercial integration of the electricity market in Central America (MER/SIEPAC). The estimate of the b-coefficient in equation (5) is -1,67 with a t-value that suggests rejection of the null hypothesis. This result, contrasted with Figure 1 is clear: although there is an initial phase in which prices tend to converge, by mid-2015 there is a breakup for more than two years.

With this observation, and the antecedent from Phillips and Sul (2009) that analyze convergence in sub-periods, we proceed to investigate further the causes of the price reduction in Costa Rica and Panama in June 2016.

Table 2. Convergence test for spot prices: June 2013 – March 2021

Sample	"b" coefficient	t-stat
Full sample	-1,668	-2,004
2013-06-01 to 2016-06-02	0,881	9,103
2016-06-02 to 2021-03-13	2,411	8,203

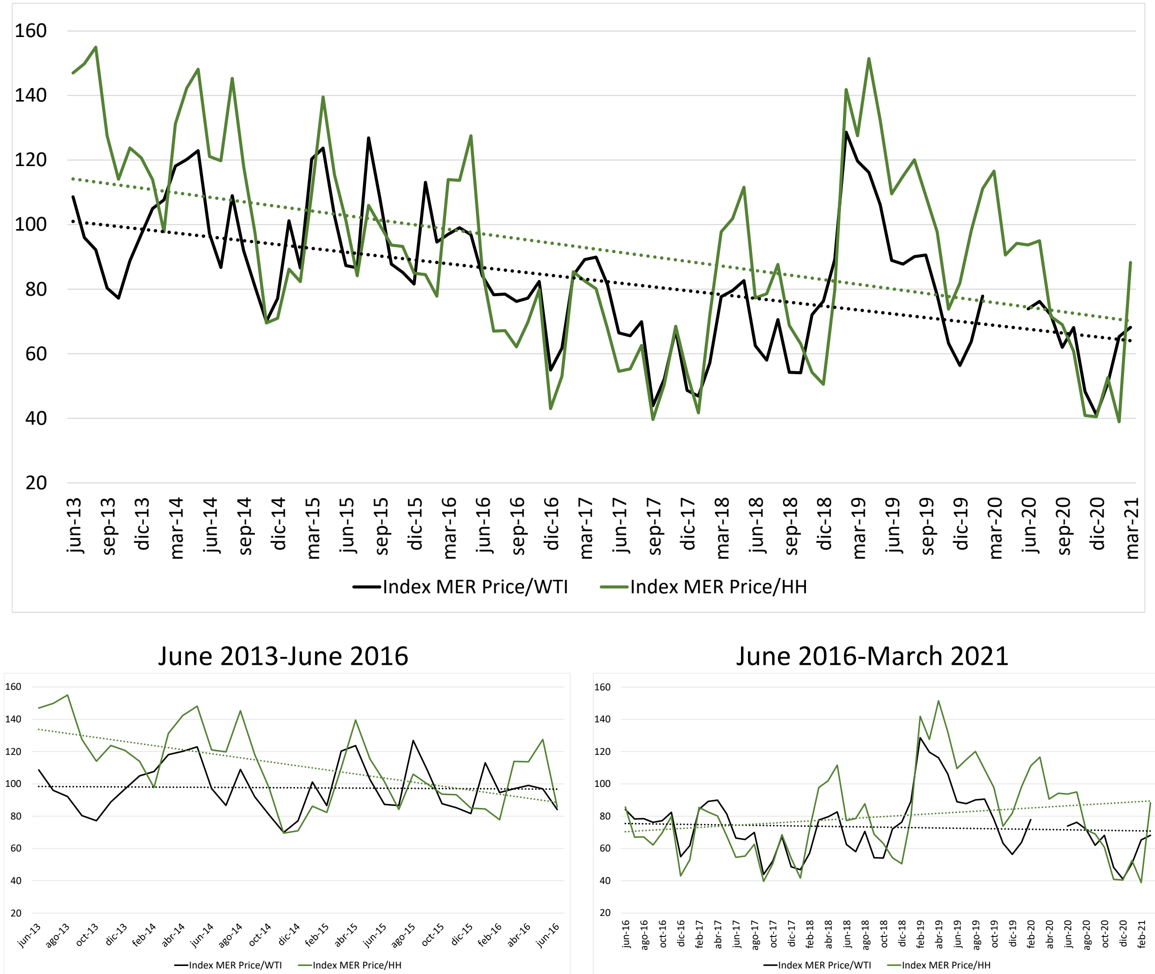
As of 2016, the *Reventazon* hydroelectric plant comes into operation in Costa Rica with an installed capacity of 300 MW. This phenomenon, added to the aggressive policy on renewable energies, achieves the objective of reducing to zero the use of thermal technology (which remains only as a backup) for electricity generation in Costa Rica. This can be seen in Figure 1: the gray bars show the months in which Costa Rica generated electricity with thermal plants at the margin. Before June 2016, this has been the situation for most of the months but became a less frequent situation ever since. During this this year, spot prices in the region divided into basically two groups. On the one hand, Costa Rica and Panama, with prices determined based on the Costa Rican system, and, on the other hand, Guatemala, Honduras, El Salvador and Nicaragua, with prices that depended on thermal generation at the margin.

This evidence led us to rerun the convergence test in two sub-periods, a first one since the formalization of MER (June 2013) to June 2016, and a second sub-period since the introduction of the Reventazon hydro plant to March 2021. Table 1 shows the statistics for both sub-periods. Table 2 shows the convergence tests by sub-periods. The main result is that the null hypothesis is not rejected neither in the first nor the second sub-period.[5] Therefore, market forces work in the direction of price convergence until the MER is shocked by a new investment (a hydro plant in Costa Rica), and eventually prices tend to converge again. It is worth noting that in the second sub-period, the reason of convergence is not a return to generation with thermal plants at the margin in Costa Rica (Figure 1 shows a very occasional use of thermal resources in that system). The alignment in prices is achieved with the strength of a system based on hydro and renewable resources. Finally, the statistical analysis not only shows convergence but also a higher speed than in the first sub-period (a higher estimate of the b-coefficient).

While the integration achieved between Central American countries is still several steps behind advanced experiences (such as in Europe), the reduction in spot price differentials among the partner countries, together with evidence of increasing transactions in MER through time, is a strong signal in favor of the integration experience and trade in the region.

[5] When using weekly data, the values of b-coefficient do not differ (0,73 and 2,34, in each sub-period), and the t-values are lower (1,09 and 2,72, respectively). The results are robust in case of using weekly data.

Figure 3. Relative price index: spot electricity prices of MER to oil, spot electricity prices of MER to natural gas. June 2013-February 2021.



Source: own elaboration based on prices from Figure 1, and price data on crude oil and natural gas published by EIA (https://www.eia.gov/).

Note: The monthly price index of spot electricity prices to crude oil (natural gas) is the ratio between both prices, and a redefinition of the base to 2015 = 100. The Price of crude oil is the West Texas Intermediate (WTI) price and the price of natural gas is the Henry Hub spot price (HH). Dotted lines are linear trends for each Price index series. We omit WTI prices from March 2020 to May 2020 due to the international conditions of the crude oil market (which displayed very low and even negative prices in some days). This omission does not alter the fact that the time trend of the price index is negative.

The reduction in spot prices shown before may be affected by the reduction in international oil prices that took place by 2015. We build indicators of relative prices between spot electricity prices in MER (a monthly average for MER prices) and oil prices (West Texas Intermediate) and natural gas prices (Henry Hub), published by US Energy Information Administration (EIA). Figure 3 shows a negative time trend of both relative prices (electricity to oil and electricity to natural gas) since the officialization and uninterrupted operation of the supra-national MER in June 2013. When decomposed into two sub-periods, we observe, first, a level effect in the relative prices to crude oil, and second, a decreasing relationship with natural gas prices, which becomes slightly positive during the second sub-period. This partial evidence, together with the convergence results, indicate that the MER influenced prices, being them less dependent of crude oil and eventually being guided by less contaminant sources of hydrocarbons such as natural gas (having introduced generation from large hydro plants and renewable sources in the generation base).[6]

5. Conclusions

The creation of a regional market (MER) accompanied by a regional interconnection system (SIEPAC) in Central America is the first multilateral experience of strong energy integration by Latin American Countries. Although many reforms are needed if partner countries wish to engage in a common market, as in the experience in Europe, the Central American experience is more advanced that the successful and unsuccessful bilateral ones in South America. A detail of future reforms related to regional coordination, long-term contracting, improvement of transmission capacity, regional-scale investments in generation and transmission, and day, intraday and balance transactions can be found in CDMER (2015 and 2020).

The SIEPAC project has been beneficial for the region, as measured by changes in producer and surplus, effects on electricity prices to productive sectors and on productive projects, but the benefits do not spread out evenly across countries (Echevarria et al., 2017). We provide evidence to two more results: price convergence, after some break up of market forces by the introduction of a hydro plant in Costa Rica, and less reliance of electricity prices on fossil fuels. The measures detailed above will strengthen these benefits in the long run.

Some of the mentioned pending reforms are worth studying. One of them is the set of regulation and institutional improvements to deepen market integration (CDMER, 2020). Other is the effects and the interrelations between market integration and the participation of renewable energy resources in the energy matrix- This was a subject of study, for example, in the European electricity market (Aatola et al., 2013, de Menezes et al., 2016, or Gianfreda et al., 2016). Also, an explicit study of the impact of MER on prices and costs, including direct and passthrough effects, and cofounding impact of complementary policies is important for the research agenda on the Central American integration experience.

[6] The purpose of this exercise is to shed light on the level at which prices converge. A full study on the effect of the MER on the level of prices should include not only the price of fossil fuels but also local policies on renewables, SIEPAC expenditures, and finally the passthrough to domestic prices to final users. This is beyond the scope of the paper.

References

Apergis, N., Fontini, F. and Inchauspe, J. (2017). "Integration of regional electricity markets in Australia: A price convergence assessment", Energy Economics, 62:411-418, doi.org/10.1016/j.eneco.2016.06.022.

Aatola, P., Ollikainen, M. and Toppinen, A. (2013). "Impact of carbon price on the integrating European electricity market", Energy Policy, 61: 1235-1251.

Batalla, J., Paniagua, J. and Trujillo-Baute, E. (2019). "Energy Market Integration and Electricity Trade", Economics of Energy & Environmental Policy, 8(2): 53-67. doi: 10.5547/2160-5890.8.2.jbat.

Bosco, B., Parisio, L., Pelagatti, M., and Baldi, F. (2010). "Long-run relations in European electricity prices", Journal of Applied Econometrics, 25(5): 805-832.

Bunn, D. and Gianfreda, A. (2010). "Integration and shock transmission across European electricity forward markets", Energy Economics, 32(2): 278-291.

CDMER. 2015. "Plan Estratégico del MER".

CDMER. 2020. "Plan Estratégico del MER 2021-2023".

Ciferri, D. D'Errico, M., Polinori, P. (2020). "Integration and convergence in European electricity Markets", Economia Politica, 37:463-492, https://doi.org/10.1007/s40888-019-00163-7.

de Menezes, L. and Houllier, M. (2016). "Reassessing the integration of European electricity markets: A fractional cointegration analysis", Energy Economics, 53: 132-150, https://doi.org/10.1016/j.eneco.2014.10.021.

de Menezes, L., Houllier, M. and Tamvakis, M. (2016). "Time-varying convergence in European electricity spot markets and their association with carbon and fuel prices", Energy Policy, 88: 613-627.

Dempster, G., Isaacs, J., Smith, N. (2008). "Price discovery in restructured electricity markets". Resources and Energy Economics, 30(2): 250-259.

Echevarría, C., Jesurun-Clements, N., Mercado Díaz, J. E., & Trujillo, C. (2017). *Integración eléctrica centroamericana: Génesis, beneficios y prospectiva del Proyecto SIEPAC: Sistema de Interconexión Eléctrica de los Países de América Central*. Recovered from https://publications.iadb.org/es/integracion-electrica-centroamericana-genesis-beneficios-y-prospectiva-del-proyecto-siepac-sistema.

EOR. (2021). *Estudio de máximas capacidades de transferencia de potencia*.

Gianfreda, A., Parisio, L. and Pelegatti, M. (2016). "Revisiting long-run relations in power markets with high RES penetration", Energy Policy, 94: 432:445.

Growitsch, Ch. Stronzik, M. and Nepal, R. (2015). "Price Convergence and Information Efficiency in German Natural Gas Markets", German Economic Review, 16(1): 87-103, https://doi.org/10.1111/geer.12034.

Kalantzis, F. and Milonas, N. (2010). “Market integration and price dispersion in the European electricity market. Energy Market (EEM) 2010”, in Proceedings of the 7th international conference on the European IEEE.

King, M. and Cuc, M. (1996). “Price Convergence in North American Natural Gas Spot Markets”, The Energy Journal, 17(2): 17-42.

Levy Ferre, Alberto, Jesús Alberto Tejeda, y Lorena Di Chiara. 2020. Integración eléctrica regional: Oportunidades y retos que enfrentan los países de América Latina y el Caribe. Inter-American Development Bank.

Li, R., Joyeux, R., Ripple, R. (2014). “International natural gas market integration”, Energy Journal, 35(4): 159-179.

Ma, H., Oxley, L. (2012). “The emergence and evolution of regional convergence clusters in China's energy markets”, Energy Economics, 34(1): 82-94.

Mercados - Aries Internacional. (2021). *Estudio de Integración Energética en América Latina. Una visión de Desarrollo al 2040*. CAF.

Phillips P. and Sul D. (2007). “Transition modeling and econometric convergence tests”, Econometrica, 75(6): 1771-1855.

Phillips P. and Sul, D. (2009). “Economic transition and growth”, Journal of applied econometrics, 24(7): 1153-1185, https://doi.org/10.1002/jae.1080

Pollitt, M. (2019). “The European single market in electricity: An economic assessment”, Review of Industrial Organization, 55: 63-87, https://doi.org/10.1007/s11151-019-09682-w.

Timilsina, G. and Toman, M. (2016). “Potential gains from expanding regional electricity trade in South Asia”, Energy Economics, 60: 6-14, https://doi.org/10.1016/j.eneco.2016.08.023

Zachmann, G. (2008). “Electricity wholesale market prices in Europe: Convergence?”, Energy Economics, 30(4), 1659-1671, https://doi.org/10.1016/j.eneco.2007.07.002.