

RSG Uplift in the Midwest ISO Footprint: Just Because the Rooster Crows¹

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Abstract. The allocation of Revenue Sufficiency Guarantee (RSG) charges at the Midwest ISO is an example of how *ad hoc* regulatory solutions, not fully supported by analysis, can have some unintended results. A cited reason for pursuing these regulatory solutions is the lack of estimates of the marginal contribution to RSG by potential causes. This work demonstrates that it is possible to estimate the marginal contribution of hypothesized causal factors to the incurrence of RSG. Using econometric methods, measures of the marginal contribution of various potential causes for RSG are estimated. These measures indicate that different factors result in quite different levels of increase in RSG. This work has resulted in the development of a probative model which could be used to craft tariff language, identify potential market distortions, and develop metrics for evaluation of RSG generating processes.

1. Introduction.

Revenue Sufficiency Guarantee (RSG) charges have been cited as both a necessity for reliable operations of the Energy market in the Midwest Independent System Operator (MISO) footprint and as a barrier to entry to market participation. The controversy over RSG arises from the size of the charge, which for the first six months of 2009 has exceeded \$61 million in the Real-time (RT) market or over 8.5 times the charge in the Day-ahead (DA) market; and, the uncertainty as to how that charge should be allocated. The process of determining a 'just and fair' allocation among market participants (MPs) has extended over four years with on-going discussions in the RSG Task Force,² and has resulted in hundreds of filings to the FERC by the market participants (MPs) in an attempt to reach resolution. And, as recent history has demonstrated, RSG provides a demonstration on how *ad hoc* regulatory solutions can have quite unintended results including failing to address the problem or making the problem worse, and driving firms to rapidly exit a market.

In the RT-market, RSG charges recover start-up, no-load and incremental costs of generators that are not recovered through sales in the Energy Market. These charges are then distributed to generators in the form of RSG Make Whole Payments (RSG MWP); and, the sum of the charges must equal the sum of make whole payments. In order to be eligible for RSG, a unit has to be offered into the DA-market, cleared, and committed during the Reliability Assessment and Commitment (RAC) process. The majority of RSG is incurred for units, such as gas-fired combustion turbines, deemed necessary for reliability purposes such as constraint management, deviations from DA-scheduled generation, load, exports and imports or forecasting errors.

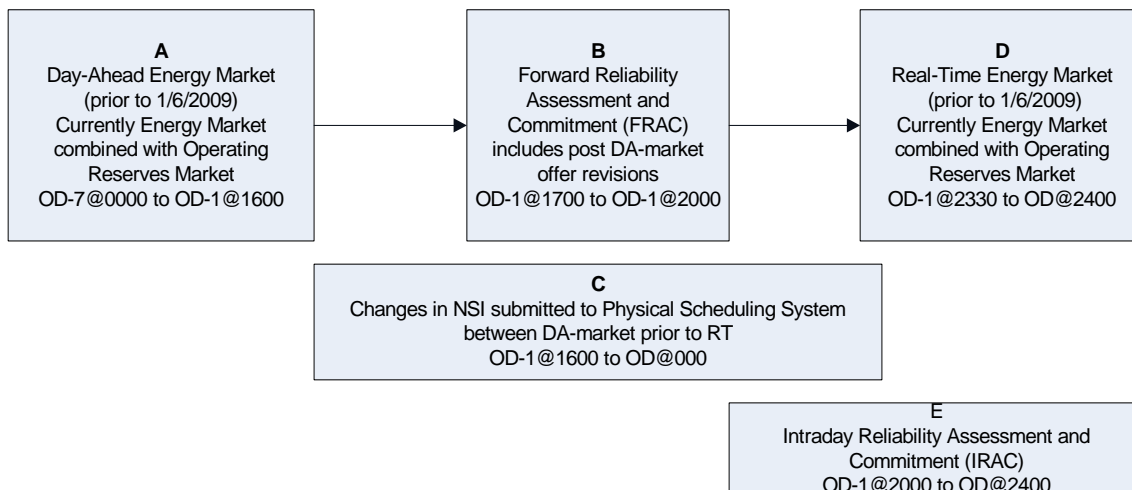
¹ The title refers to an oft cited reason for not using correlation coefficients to prove causality.

² The Midwest ISO is governed by various committees of stakeholders. These committees in turn establish task forces and working groups to address specific issues (MISO 2008)

However, units that are actually dispatched also may be eligible for RSG MWP. These units may be removed from the MISO system for the same reasons as units are dispatched. Therefore, in the RT-market, the potential causes of RSG are more numerous than in the DA-market where constraint management is the only source. Also, in the RT-market, these potential causes can interact re-enforcing or off-setting another potential cause, and all of this within a dispatch period of less than five-minutes.

The MISO operates two Energy and Operating Reserve Markets, a DA- and a RT-market. In January 2009, the MISO added an Ancillary Services Market (ASM), and the Energy and ASM are not co-optimized (MISO 2009a). Prior to January 2009, the DA- and RT-markets were 'energy only'; the MISO does not operate capacity markets as are found in several other ISOs such as PJM. The DA-market (Figure 1, Stage A) is a forward market where load is bid and generation is offered; the market is cleared by ensuring supply offers meet demand bids subject to reliability considerations. This market provides MPs the opportunity to hedge pricing and quantity risks during the operating day. Participants in the DA-market do have the opportunity to employ financial or virtual instruments in hedging strategies. At the close of the DA-market, but prior to the start of the RT-operating day, a forward reliability assessment and commitment process (FRAC) (Figure 1, Stage B) is run. During the FRAC process financial transactions are removed, and a load forecast is used to ensure that supplies are sufficient to cover anticipated load. During the operating day, the RT-market (Figure 1, Stage D) is run in 5-minute increments and cleared as opposed to the hourly increments used in the DA-market. Once again, the RT-market is subject to reliability concerns, and as part of this process, during the operating day, the Intraday Reliability Assessment and Commitment (IRAC) (Figure 1, Stage E) is conducted at frequent intervals. Although, imports and exports are scheduled into the DA-market, MPs can change scheduled volumes after the FRAC ends but prior to the start of the operating day (Figure 1, Stage C), and then during the operating day. This adds an additional set of uncertainties to the IRAC.

Figure 1. Time-line between DA- and RT-Markets



Taken from: Exhibit 2-1
(MISO 2009a)

The development of tariff components for the allocation of RSG MWP has proven to be a difficult and often contentious issue. A good tariff for such a measure should allocate or assign charges on the basis of causality or the entity that causes a problem pays for correction. This is a long-established rule in the courts and administrative law that produces the most economically efficient solution. However, with respect to a charge that can be caused by any number of events, often many which occur simultaneously, this has proven to be a difficult task which has yet to be performed. Further, a good tariff should provide those subject to its provisions an indication of potential liability if an entity causes an event. None of the current proposals for RSG allocation provide an *ex ante* pricing signal; all are *ex post* and more of an accounting mechanism. As such, MPs in the MISO are often surprised at the level of individual charges, and have been literally 'put out of business' by the unexpected size. A good tariff should also provide flexibility, equity, transparency, and remove uncertainty. Examination of the current RSG tariff re-design proposals indicates that those characteristics are probably not met. This is largely due to the absence of identification of the linkage between costs and cause, and the development of a marginal contribution for each potential causative factor.

In the work presented here, econometric methods are applied to the issue of RSG. Using an estimated model for data over a three year period, marginal contributions to RSG are calculated for a number of factors that are thought to cause RSG. This analysis, not only demonstrates that this can be done, but also supports the contention that different causal factors result in different levels of increase in RSG MWP. Some of the factors have much greater impacts than previously thought, while others have much smaller impacts. However, these results are largely dependent upon the public availability of data, and could change with better definition of the explanatory variables at a nodal level. The remainder of this paper is organized as follows. Section 2 provides a brief summary of the regulatory background since the beginning of consideration of RSG. Section 3 discusses the sources of data for this analysis, the model specification along with definitions of variables, and the estimation techniques. Section 4 presents the results of the econometric model, the calculation of the marginal contributions, and caveats. Finally, Section 5 provides some brief concluding remarks.

2. Regulatory Background.

The current RSG 'redesign' effort has extended at this point almost four years, and will probably continue over the next several years. Starting in October 2005 with a filing to the Federal Energy Regulatory Commission (FERC) under Section 205 of the Federal Power Act (FPA), the MISO proposed three improvements to the Open Access Transmission and Energy Market Tariff (TEMT) with other clarifications relating to RSG costs and charges (MISO 2005).³ The improvements were designed to support the further development of the competitive wholesale market in the MISO footprint. One of the key improvements removed references to virtual supply offers (VSO) from the TEMT provisions relating to the calculation of RSG charges; the MISO argued that since virtual trades did not involve the delivery of physical energy and were removed during the FRAC, they were not a source of increased costs during that process. This improvement

³ FERC in its deliberations on this docket also considered related filing made under Docket Nos. ER04-691-065, -074, -078, -081, -084, -085, -086, -088, and -089. As a result of these deliberations, FERC has issued several orders, orders on rehearing, orders on compliance filings and several appeals to the Court of Appeals for the District of Columbia Circuit.

was argued to have benefits for the MISO energy markets similar to those observed in other wholesale markets where virtual trading increased (Isemonger 2006). In resolving this matter, FERC rejected the MISO's proposed changes to the TEMT concluding that virtual supply offers did cause costs during the RAC to increase and should be included in the calculation of RSG charges. However, that conclusion was reached on the basis of one example that was shown to be incorrect by four separate subsequent critiques which were never answered by the FERC (DC Energy Midwest LLC and Integrys Energy Services Inc. 2008). Ultimately, the matter was decided on the basis of whether the MISO's proposed changes were 'just and reasonable'; the FERC concluded that the proposed changes were not just and reasonable, but the existing allocation method⁴ in the TEMT was.

In August, 2007, several parties filed complaints against the MISO under Section 206 of the FPA. These complaints charged that the RSG cost allocation mechanism in the MISO TEMT was unjust and unreasonable, because RSG charges were only imposed on market participants physically withdrawing energy from the RT market. In these complaints, FERC was requested to find the RSG allocation method then defined in the TEMT to be unjust and unreasonable, set the matter for hearing and establish a refund effective date. FERC issued an order in response finding that the RSG allocation method might be unjust, unreasonable, and unduly discriminatory. The order further established a paper hearing process that was to be held in abeyance pending conclusion of the ongoing stakeholder process on RSG charges or February 1, 2008, whichever occurred earlier. MISO was directed to provide an informational filing on February 1, 2008 on the status of the stakeholder process. At that time, the FERC would establish a schedule for the paper hearing if the stakeholder process had failed to develop an alternative RSG cost allocation method.

On March 3, 2008, the MISO submitted a filing to the FERC proposing TEMT revisions incorporating an alternative RSG allocation proposal. This proposal had evolved from a white paper⁵ and some analysis based largely on correlation techniques prepared by MISO staff. Several parties filed protests and comments on this filing (DC Energy Midwest LLC and Integrys Energy Services Inc. 2008). Specifically, these responses explicitly raised the point that correlation analysis was not evidence or proof in and of itself of cost causality. Further, on August 1, 2008, a motion was filed by one of the MPs urging the FERC to commence paper hearings leading to the resolution of the disputes over RSG charges. This request for expedited consideration was supported by a number of other parties. Subsequently, FERC issued an order on August 21 providing a schedule for this process.

The Paper Hearing held in November revolved around several issues that had reoccurred throughout the course of this set of dockets. The central issue to the discussion was the lack of evidence showing causality and more importantly the extent of causality or the marginal contribution to causality. Previously in October 2006, FERC had ordered the MISO to perform simulations with the market models to estimate the specific contribution of virtual supply offers to the incurrence of RSG (Hogan 2008). In March 2007, the MISO responded that those simulations could not be performed due to difficulties in identifying reasons for commitment of specific units in

⁴ The initial MISO TEMT which was affirmed in 2004 by the FERC applies RSG charges to only market participants that actually withdraw any Energy on a given day (AWE).

⁵ This paper entitled: "Revenue Sufficiency Guarantee (RSG) Redesign" is available at http://www.midwestiso.org/publish/Document/283d13_11760720eb8_-7f030a48324a?rev=7.

the RAC. Therefore, no evidence could be provided to demonstrate the actual contribution of virtual supply offers (or any other factor) at that time. Further, during the Paper Hearing, comments were offered to the FERC citing the inappropriate use of correlation coefficients to show causality; that no probative model that included all factors that could cause RSG existed; and, that no credible evidence had been put forward to either support or negate any cost allocation proposal (Greening 2008). Despite the lack of evidence on cost causality, the FERC on November 10, 2008 issued an order accepting the interim and 'indicative' tariffs, and ordering the MISO to resettle the market from August 10, 2007; and, to go forward using the 'interim' rate until such time as the 'indicative' tariff was ready for implementation under ASM (FERC 2008).

After the issuance of the 'Paper Hearing Order' on November 10, the MISO filed a compliance order in December and began the re-settlement process. The method used in the re-settlement imposed 40% of real-time RSG costs on VSOs. In February, 2009, this allocation was termed unjust and unreasonable and inconsistent with cost-causation in a filing to the FERC by the MISO independent market monitor (IMM) (Patton, 2009). Further, as a result of the re-settlement, cleared virtual supply in January 2009 was 60% lower than in the fall of 2008, and by the time of the filing of the IMM, 13 MPs, who traded in VSOs, were either in default or past due. Ultimately, 18 MPs would enter into default with two declaring bankruptcy, and the amounts in default (roughly between \$12 and \$89 million) would need to be uplifted to the market. Finally, the MISO apprised the FERC that there would be an estimated \$89 million shortfall in collateral due to the re-settlement. On May 6, in response to a writ of *mandamus* filed by some of the MPs who deal in financial trades, FERC reversed itself on re-settlement and ordered the MISO to cease re-settlement; and, granted partial re-hearing of the 'Order on Paper Hearing' (FERC 2009). At this point in time, the issue of cost causality remains un-resolved, and various parties continue discussions in one form or another.

3. Method of Analysis.

This section summarizes the data available on the MISO website for analysis of RSG, the econometric specification used in our analysis along with definition of the variables along with the calculation of marginal impact factor for each variable, and the techniques used in estimation.

a. Data Available.

All data utilized in this analysis is publically available and was extracted from the website of the Midwest ISO. These data are reported hourly at the MISO footprint level and made available on an on-going basis on the day after a specified market day. Data on the DA market (Figure 1, Stage A) was extracted from the DA Report (MISO 2006a) which summarizes volumes of demand (physical, price sensitive, and virtual bids), supply (physical and virtual offers), and net scheduled imports cleared in that market. In addition the report includes summaries of physical generation offers into the market on the basis of type (self-scheduled, must run, economic and emergency). Results of the FRAC and RT market (Figure 1, Stages B and D) are reported in the Real-time Report (MISO 2006c). Variables reported for both the FRAC and RT-market include Economic Maximum⁶ (Econmax), load, net scheduled imports (NSI), and outage volumes. Numbers of

⁶ Economic Maximum is defined as the maximum Energy available, in MW, from a Resource under non-Emergency conditions and is specified in both DA and RT offers (MISO 2009a).

binding constraints are reported for real-time. Because not all load is bid or obligated into the DA-market, a load forecast is input into the FRAC. Hourly values for the Mid-term Load Forecast (MTLF) and actual load as measured by the state-estimator are reported in the Regional Forecast and State Estimator Report (MISO 2007). Finally, data on net scheduled interchange are available from the Interchange Summary Report (MISO 2006b).

b. Model specification.

RSG represents an implicit or opportunity cost to participants in the MISO markets. That is, RSG covers some of the costs of maintaining smooth operations in the RT market in a reliable fashion, and as a result, market participants must support the sacrifice a certain number of kilowatt hours to support those purposes (Henderson and Quandt 1971). As previously discussed, these costs result from changes in operations or departures from the competitive paradigm (cost minimization). And, allocation of these opportunity costs requires an understanding of the marginal contribution of a variety of potential causes to the incurrence of these costs. Each potential cause of RSG may not in and of itself generate the opportunity cost, but the simultaneous occurrence of several causes and their interaction can. Therefore, the problem becomes one of estimating a relationship between the cost, the primary factors, and the interactions among factors.

Underlying production in a firm, or aggregated to the level of a market, is a cost function which is determined by the inputs. This function is implicitly separable into cost functions for each of those inputs (Blackorby et al. 1978). This concept has been used in the development of incentive indices that have application to firms in deregulated electricity markets (Diewert and Fox 2000). Opportunity costs are an input into the output of electricity in an energy market, and as such we are justified in using standard techniques for the estimation of the marginal contribution of each input or factor leading to these costs. In other words, as with the private costs of production, opportunity costs such as RSG uplift have their own cost function determined by the factors contributing to incurrence. Further, that cost function is separable from other costs, and as such can be estimated independently.

Flexible functional forms have been used to estimate cost functions and to determine the marginal contribution of a factor to costs previously. Any cost or production function specification that satisfies the required regularity conditions and results in a second order approximation to a twice differentiable function can be termed as a flexible form (Diewert 1973). A number of different forms have been utilized for this class including the well-known translog, the semi-log quadratic, and the simple quadratic functional forms (Diewert and Wales 1987). For this work, we have selected a simple quadratic functional form due to the potentially high number of negative values for independent variables, the potential for zero values for the dependent variable, the capability for modeling the joint occurrence and interaction of uplift causing events during any given period of time, and the ease of interpretation of the results. This functional form has been used extensively in such applications as the estimation of the marginal prices of consumer product attributes (Cropper et al. 1993; Greening et al. 1997), the marginal contribution of various factors to pollution abatement expenses (Cebula et al. 2008), and evaluating the efficiency of mergers in the electricity industry (Hartman 1996a and b).

Using a fully expanded quadratic specification, the functional form used in this analysis is as follows:

$$RSG_MWP = \sum_{i=1}^k \varphi_i y_i + \sum_{i=1}^n \delta_i X_i + \frac{1}{2} \sum_{i=1}^n \sum_{j=1}^n \beta_{ij} X_i X_j + \sum_{i=1}^m \gamma_i D_i + \varepsilon \quad (1)$$

where

RSG_MWP = hourly RSG Make Whole Payment (\$/MW)

φ, δ, γ = vectors of estimated parameters

β = matrix of estimated parameters

X = continuous variables defined in Table 1

D = vector of binary variables controlling for differences between peak and off - peak hours, winter and summer months, and other factors (see text)

y = vector of binary variables for years 2006, 2007, and 2008

ε = residual term

The marginal contribution of each continuous factor to RSG MWP can be evaluated using the partial derivative of RSG MWP with respect to each continuous variable. These values are linear combinations of the estimated coefficients and the explanatory variables utilizing the following expression:

$$\frac{\partial RSG_MWP}{\partial X_j} = \delta_j + \sum_{i=1}^n \beta_{ij} X_i \quad (2)$$

The coefficients of the quadratic terms are particularly useful for this analysis since they represent the contribution of one factor in the presence of another, i.e., when two events occur during the same period of time, opportunity costs are allocated to each event. However, it should be noted that the value of the marginal contribution for each factor will change based on the point where the evaluation occurs. That is the marginal contributions are not constant and are nonlinear; the nonlinearity appears when calculating confidence intervals. Further, the results of Equation (2) can be used to develop a scaled or normalized rate of change at the points of evaluation. However, that was not done here, and would be useful in further analysis.

Definitions, along with sign conventions used, for the continuous variables in our model specification are summarized in Table 1. Descriptive statistics for these variables are provided in Table 2 for the entire period (all hours and hours with zero RSG), and the sub-periods before and after the start of ASM. This data set includes the period from June 1, 2006 to June 1, 2009 or three years, and all data is on an hourly basis. The dependent variable is defined as the RT RSG MWP in real dollars per MW of Econmax eligible to receive RSG (MISO 2006d). Previous analysis provided by the MISO indicates that a positive correlation probably exists between this variable and the number of MWs of Econmax and number of units eligible for RSG MWP (MISO 2009b). To obtain a real or constant dollar value for RSG MWP, we used the PPI deflator for electricity generation (Bureau of Labor Statistics 2009). This deflator is based on the fixed and variable operating costs of generators, and does not include capital expenditures. The use of this deflator was dictated by the lack of information on fuel type for units receiving RSG MWP. As previously discussed, RSG MWP are not necessarily restricted to gas-fired combustion turbines dispatched to

manage system conditions, but can also include other generation fuel types where a unit has been committed and dispatched and is later decommitted. The month of June, 2006 was used as the basis for deflation, and as a result, this variable has been converted to real or constant June 2006 dollars.

Table 1. Definitions of variables

Variable (all variables are hourly measures)	Definition	Sign Convention with Rationale
RT RSG MWP	RT RSG Make Whole Payments per MW of Econmax eligible for payment	Positive value deflated to June, 2006
Difference in physical load committed in FRAC and cleared in DA (FRAC-DA)	Obligated physical load above and beyond the sum of fixed and price sensitive loads cleared in the DA market (in GW).	Increase indicates capacity required (positive sign).
Change in load during RT (RT-FRAC)	Difference between RT load and load committed during FRAC (in GW).	Decrease indicates less capacity required (negative); increase indicates more capacity required (positive).
Change in offers during RT (RT-FRAC)	Difference in Economic Maximum due to changes in offer parameters (e.g., ramp capability, unit availability) during RT (in GW).	Increase in Econmax indicates less capacity required in RT (negative); decrease in Econmax indicates more capacity required (positive).
Change in Econmax during RT (RT-FRAC)	Difference between RT Econmax and FRAC committed Econmax (in GW).	Increase in Econmax indicates less capacity required in RT (negative); decrease in Econmax indicates more capacity required (positive).
Headroom proxy	Load covered in FRAC less Econmax committed in FRAC less NSI in FRAC (in GW).	Negative indicates less potential for use of headroom during RT; positive indicates more potential for use of headroom during RT.
Number of binding constraints	Positive integer value for number of binding constraints during RT.	Increase in number means potential increase in required capacity (positive).
Virtual supply offers	Financial offers of capacity in DA-market (in GW).	Virtual supply requires an additional commitment of capacity during the FRAC (positive).
Load forecast (MISO footprint)	Difference in GW between MTLF and State Estimator (measure of actual load) in GW.	Over-forecast implies less capacity required in RT (negative sign); under-forecast requires more capacity in RT (positive sign).
Change in NSI between the FRAC and 12:00 a.m. (PJM versus Other Tier 1 interchanges)	For PJM and Other Tier 1, NSI reported in physical scheduling system after the close of DA- and end of FRAC but before 12:00 a.m. (in GW).	Net injection implies less capacity required in RT (negative sign); net withdrawal requires more capacity in RT (positive sign).
Change in NSI after 12:00 a.m. in RT (all interchanges)	The variable after 12:00 a.m. captures changes in NSI made in real time (in GW).	Increase in NSI during RT (positive); decrease in NSI during RT (negative).

Calculation of the majority of the variables defined in Table 1 is relatively straight-forward. For example, variables such as the 'change in load during RT' are calculated as the difference between two measures from the RT Report, while variables such as 'virtual supply offers' were extracted directly from the DA report. However, three of the variables, the headroom proxy, forecast error, and net scheduled imports require additional discussion.

Headroom⁷ provides the slack in the system for unanticipated events during RT such as unscheduled fluctuations in NSI or increases in demand or the sudden loss of generation capacity. Headroom is a tool in maintaining the reliability of the system. A direct measure of this quantity was not available; and, the MISO does not publicly release this measure nor are all of the components of the definition available. However, a 'proxy' measure could be constructed from the available data that includes the major components of the definition. Examination of this proxy variable (as defined in Table 1) in comparison with RSG MWP indicates a positive correlation. Therefore, this measure is referred to as representing potential need for headroom. As a caveat, should an actual measure of headroom become available the results presented here could very well change. The actual value for headroom would be smaller than the proxy variable due to reductions for a reserve requirement and an explicit reduction in capacity due to constraints.

Forecast error is defined as the difference between the MTLF adjusted for other loads such as pumped storage, and the hourly integrated state estimator (MISO 2007). The MTLF is generated on a daily basis by the MISO, and used as an input to the FRAC. Hourly integrated state estimator values are reported as a proxy for real-time load; use of the state estimator value filters measured load for extreme values. Since the direction of error (over forecast versus under forecast) is as important as the magnitude, the convention has been followed that a positive value represents an under forecast (additional capacity required during RT) while a negative value represents an over forecast. This variable is defined as a volumetric measure in GW.

Net scheduled imports or interchange activity between the MISO and its neighbors are reported at several points in the RAC process and then during real-time; further, these values are reported for Tier I interchanges such as with PJM, TVA, SPP, and as a total for all interchanges (MISO 2006b). Hourly detailed reports of interchange activity are provided at three different points during commitment and the real-time market. Our analysis found that the values reported as planned in the physical scheduling system and used in the DA-market are also used in the FRAC process for commitment purposes. However, after the FRAC, but before the beginning of the RT-market (12:00 a.m.), interchange values do undergo a dynamic update. Interchange values during this time period vary substantially. Therefore, for this period of time, we have used two different variables, NSI at the PJM interchange, or a market-to-market interchange, and NSI as a total of all other interchanges, or non-market to market, in our econometric specification. However, the MISO does not provide similar detail for changes in interchange that may occur during the operating day (after 12:00 a.m.). To capture any remaining changes that occur during the operating day, we use the difference between the RT-market hour and total scheduled NSI during that hour at the beginning of the operating day at a footprint level of aggregation.

Binary or dummy variables are included in our specification to allow for time trends, and to control for shifts between peak and off-peak periods such as the diurnal cycle or seasonal shifts. Binary variables for the years 2006 through 2008 control for secular effects (or inflation) not accounted for by the deflation of RSG MWP, and for possibly some differences in general weather patterns. In addition, seasonal variables for winter (November 15 through March 15) and for

⁷ MISO Operations defines this variable as the sum of negative dispatch maximum of on-line resources, negative NSI, negative load obligation, negative online reserve requirements, and negative constraint stranded capacity with withdrawals (load and NSI) by convention having a negative sign (MISO 2009).

summer (May 15 through September 15) were also defined. Diurnal differences were controlled for by peak (hours ending 6 through 22) and off-peak. Finally, binary variables were defined for the FERC order of November 10 and for the implementation of ASM starting on January 6, 2009.

Table 2. Means of continuous variables

Variable (standard deviation in parentheses)	Whole period	Hours with Zero RSG MWP	Before ASM	After ASM
Number of observations	26297	5649	22793	3504
RT RSG MWP (Real 2006\$/MW)	1.9366 (2.4770)	0.0000 (0.0000)	1.9222 (2.4135)	2.0301 (2.8545)
Difference in physical load committed in FRAC and cleared in DA (FRAC-DA) (GW)	3.1220 (1.8734)	3.3610 (1.1047)	3.0660 (1.1755)	3.4850 (1.1270)
Change in load during RT (RT-FRAC) (GW)	0.0949 (1.7101)	-0.4191 (1.4884)	0.1645 (1.7506)	-0.3579 (1.3335)
Change in offers during RT (RT-FRAC) (GW)	0.5255 (0.9173)	0.5941 (0.8698)	0.4228 (0.8344)	1.1943 (1.1272)
Change in Econmax during RT (GW)	0.1511 (1.8734)	-1.3066 (1.6170)	0.0299 (1.8524)	0.9394 (1.8171)
Headroom proxy (GW)	-3.7241 (4.3463)	-7.8210 (4.2053)	-3.52299 (4.4189)	-4.9880 (3.5938)
Number of binding constraints	1.8500 (1.6431)	1.5470 (1.3969)	1.8130 (1.6413)	2.0920 (1.6346)
Virtual supply offers (GW)	4.2520 (1.7629)	3.6200 (1.3108)	4.5543 (1.6528)	2.2849 (1.2907)
Load forecast (MISO footprint) (GW)	-0.7340 (2.0873)	-0.6825 (1.7606)	-1.1997 (1.7611)	2.2960 (1.3893)
Change in NSI at PJM interchange between the FRAC and 12:00 a.m. (GW)	-0.2857 (0.5923)	-0.2185 (0.4610)	-0.2811 (0.5981)	-0.3162 (0.5524)
Change in NSI at Other Tier 1 interchanges between the FRAC and 12:00 a.m. (GW)	0.4730 (0.7686)	0.4001 (0.6740)	0.4379 (0.7815)	0.7008 (0.6331)
Change in NSI after 12:00 a.m. in RT (all interchanges) (GW)	-0.0240 (0.3075)	0.0429 (0.2820)	-0.0201 (0.3127)	-0.0496 (0.2697)

c. Estimation techniques.

Estimation of the relationship expressed in Equation (1) involves a common problem in econometrics and many other disciplines where statistical analysis is used.⁸ The variable RSG MWP is left censored at zero. That is this variable is positive for the majority of observations and zero for the remainder even though the covariates have non-zero values and this information has value. As a result, the distribution underlying the dependent variable is a combination of discrete and continuous variables (Greene 1993, 1997). A number of techniques have been applied to this estimation problem including probit maximum likelihood, least squares, Heckman's two-step least squares, nonlinear least squares, nonlinear weighted least squares, and Tobit maximum likelihood (Amemiya 1985). All of these methods with the exception of the Tobit maximum likelihood are not fully efficient or result in biased coefficient estimates. However, because the issue of censored data

⁸ For a listing of some of the applications where censored variables have been present see Amemiya (1985).

is such a common problem, most statistical packages have a Tobit maximum likelihood routine implemented, and as such the ease of working with this type of data has been substantially increased.⁹

For the work presented here, Equation (1) was estimated with maximum likelihood assuming a 'gaussian' or normal distribution. To ensure robust standard errors where misspecification errors such as heteroscedasticity are often found in association with cross-sectional data, a White's estimator was used (White 1980; Zeileis 2004). This correction will provide robust standard errors assuming other misspecification errors are not present. Perhaps the most fatal error for maximum likelihood is the specification of the distribution underlying the dependent variable (Greene 1993, 1997). Prior to estimation we performed several standard tests for normality of this variable. Those tests included the Anderson-Darling, Cramer-von Mises, and the Lilliefors (Thode 2002).

4. Discussion of Results.

For our analysis of the factors associated with the incurrence of RSG MWP, we use two lines of evidence: 1) the estimated model results; and 2) the marginal contribution of each factor derived from our estimated model.

a. Estimation results.

Tables 3a and b provide the estimated coefficients for the explanatory variables used in the econometric model of RSG MWP. Test statistics at the bottom of Table 3b indicate that the model is very significant, and over 80% of the estimated coefficients are significant at levels of 90% or better. The hypothesis that models should be estimated for sub-periods of whole analysis period, e.g., before and after the start of the ASM market, was evaluated. Statistical tests did not reject the hypothesis that the coefficient vectors are the same for both periods. This is an understandable result given that our data set represents 2 years and 7 months of experience prior to the initiation of ASM, and only five months after. Also, until the 'indicative' tariff for RSG is actually implemented, the current 'interim' tariff, which is a modification and not a significant change, is in effect. Therefore, a true structural break has not occurred in the processes that generate RSG, and we use the estimated model for the whole period for the remainder of the analysis presented here.

Examination of the coefficient estimates on Table 3a provides an indication of the primary effects of various factors thought to cause RSG. Those coefficient estimates are presented in the first row of Table 3a. Seven of the eleven factors thought to be associated with the incurrence of RSG have coefficient estimates that are statistically significant at the 95% level or higher. Also, all seven of these factors indicate an increase (or positive effect) in RSG MWP. The greatest impact or increase in RSG MWP is associated with changes in all supply offers (i.e., economic, self-scheduled, and must run) during RT. Deviations in Econmax and load from committed schedules in

⁹ For this work, an open source package known as R (available for download from <http://CRAN.R-project.org/>) was used. R is a statistical and data analysis and graphics package implemented in S, a object-oriented language developed at Bell Laboratories in the late 1970s (Kleiber and Zeileis 2008). The package is supported by an international team of research statisticians and econometricians, and has approximately 2/3 again the number of statistical algorithms and routines as the widely used commercial packages. As of March, 2009, SAS, one of those commercial packages, provides a call facility to directly access and use R.

the FRAC account for the next greatest increases in RSG MWP; while, load covered in FRAC, both of the NSI measures between the FRAC and 12:00 a.m., and the headroom proxy also result in an increase in RSG MWP. The other four factors, including VSO, do not have any primary effects, i.e., coefficient estimates are insignificant. However, from the number of highly significant coefficients for the cross-products, marginal effects appear to be substantial for all of the variables included in this analysis. Therefore, in order to draw conclusions concerning the true impacts associated with various factors assumed to cause RSG, the marginal contribution of each needs to be calculated using the expression in Equation (2).

The coefficient estimates for the binary variables specified in the model are presented in Table 3b, and these provide additional information. There are statistically significant diurnal and seasonal effects as well as differences between years. The annual effects (i.e., the yearly binary variables) as previously noted would capture any secular changes (or inflation) not removed by the deflation of the RSG MWP as well as general differences in weather, i.e., a colder winter than other years. Also, the binary variables indicating the periods after the FERC RSG order in November, 2008 and after the beginning of ASM are significant. Much of that significance could be attributed to the rapid and pronounced decline in virtual trades subsequent to the FERC RSG order, and the uncertainty associated with the start of the ASM. Further, statistical comparison of the means of the other variables (see Table 2) of the periods before and after ASM indicate other differences, e.g., such as all of the deviation categories increase and forecasted load reverses sign indicating an underforecast as opposed to an overforecast. Coincident with the initiation of ASM, the Midwest was subject to a period of unseasonably cold temperatures which may have been somewhat controlled for in this modeling exercise, but not completely. Therefore, until a longer history of experience after ASM exists, we can not say definitively that a structural change or shift occurred as a result of these events.

b. Marginal contributions to RSG MWP.

Table 4 provides estimates of the marginal contribution for each of the factors included in our econometric model. By utilizing the means of the continuous variables for three different periods, the entire period and before and after the initiation of ASM, along with our estimated model results in Equation (2), we were able to calculate marginal contributions for the factors depicted in our model. As part of the evaluation process, lower and upper bounds were also calculated.¹⁰ Using those marginal contributions, we are able to draw conclusions concerning the factors hypothesized to cause RSG and specifically comment on the impacts of the decline in virtual supply offers since the beginning of 2009 (subsequent to the November FERC order). Taking our analysis one step further, we evaluate the possibility of the total cessation of all virtual supply offers from the MISO market *ceteris parabis* (i.e., virtual supply offers go to zero while all other factors remain at the mean levels for the entire period). This scenario further clarifies the relationship of virtual supply

¹⁰ Upper and lower bounds were calculated using the jointly determined coefficients at a 90% confidence level and the 90% confidence interval for the means of each of the explanatory variables.

Table 3a. Estimated Coefficients for Continuous Variables for the Whole Period

Variable (standard errors in parentheses)	Diff. in physical load (FRAC- DA)	Change in load during RT (RT- FRAC)	Change in Offers during RT (RT-FRAC)	Change in Econmax during RT (RT-FRAC)	Headroom proxy	Number of binding constraints	Virtual supply offers	Load forecast (MISO footprint)	Change in PJM NSI between FRAC and 12:00 a.m.	Change in Other Tier 1 NSI between FRAC and 12:00 a.m.	Change in NSI after 12:00 a.m. in RT
Parameter estimates (primary effects)	0.514*** (0.098)	0.711*** (0.073)	1.031*** (0.088)	0.808*** (0.063)	0.098** (0.035)	-0.078 (0.048)	0.040 (0.070)	0.012 (0.056)	0.515*** (0.138)	0.228* (0.108)	-0.306 (0.265)
Cross products											
Diff. in physical load (FRAC-DA)	0.022* (0.009)										
Change in load during RT (RT-FRAC)	-0.063*** (0.013)	-0.041*** (0.007)									
Change in Offers during RT (RT-FRAC)	-0.047** (0.016)	0.043** (0.014)	0.041*** (0.012)								
Change in Econmax during RT (RT-FRAC)	-0.051*** (0.011)	0.076*** (0.010)	0.035** (0.013)	0.034*** (0.001)							
Headroom proxy	0.041*** (0.006)	0.009† (0.005)	0.011† (0.006)	0.017*** (0.005)	-0.002† (0.001)						
Number of binding constraints	-0.008 (0.008)	0.057*** (0.007)	0.012 (0.010)	0.005 (0.007)	-0.016*** (0.003)	0.015*** (0.003)					
Virtual supply offers	-0.023* (0.010)	-0.074*** (0.009)	-0.110*** (0.011)	-0.052*** (0.008)	-0.016*** (0.004)	-0.001 (0.006)	0.024*** (0.005)				
Load forecast (MISO footprint)	0.040*** (0.010)	0.022** (0.008)	-0.075*** (0.011)	-0.051*** (0.008)	0.008* (0.004)	-0.054*** (0.006)	0.005 (0.008)	-0.003 (0.004)			
Change in PJM NSI between FRAC and 12:00 a.m.	-0.084*** (0.025)	0.013 (0.024)	-0.008 (0.028)	0.037† (0.020)	0.045*** (0.012)	0.065*** (0.014)	-0.049** (0.017)	-0.041* (0.018)	-0.077*** (0.021)		
Change in Other Tier 1 NSI between FRAC and 12:00 a.m.	-0.076*** (0.020)	-0.082*** (0.018)	-0.108*** (0.023)	0.066*** (0.016)	-0.006 (0.008)	-0.016 (0.012)	0.017 (0.014)	0.069*** (0.015)	-0.196*** (0.030)	-0.005 (0.016)	
Change in NSI after 12:00 a.m. in RT	0.087† (0.047)	0.104* (0.041)	-0.183*** (0.052)	-0.179*** (0.038)	-0.051** (0.019)	-0.042 (0.030)	-0.022 (0.034)	-0.038 (0.033)	0.004 (0.076)	-0.029 (0.065)	0.045 (0.047)

Table 3b. Estimated Coefficients for Binary Variables for the Whole Period (standard errors)

Variable	Parameter Estimates
	-0.517
Peak hours	(0.403)
	-1.622***
Off peak hours	(0.407)
	-0.672***
Summer months	(0.042)
	0.605***
Winter months	(0.039)
	0.956***
Year 2006	(0.246)
	0.648**
Year 2007	(0.244)
	0.060*
Year 2008	(0.241)
	-1.047***
FERC RSG Order	(0.079)
	1.085***
Ancillary services market	(0.247)
	0.796***
Log(scale)	(0.005)

***Statistically significant at the 0.999 level

**Statistically significant at the 0.99 level

* Statistically significant at the 0.95 level

†Statistically significant at the 0.90 level

Log-likelihood: -49290 on 87 DF

Wald-statistic: 32890 on 85 DF, p-value < 2.22e-16

McFadden pseudo R²: 0.1314

Akaike's IC[intercept only]: 113701.7

Akaike's IC[estimated model]: 98756.32

offers to the other factors and to the generation of RSG uplift. And, as such, we can also calculate a value that trades in virtual supply offers bring to other market participants through a potential offsetting effect to other RSG generating factors.

The results for the whole period indicate that the majority of factors identified as causes of RSG uplift are associated with increases in this cost. However, those marginal contributions vary substantially in magnitude between factors. The greatest single marginal contribution is from both positive and negative deviations of RT NSI after 12:00 a.m., and accounts for not quite 30% of the marginal contribution to RSG. However, deviations by generators through changes in bid parameters (from all types of generation) or in changes in Econmax during RT account for approximately 39%. Once again both positive and negative deviations for both of these sources account for increases in RSG. Load accounts for approximately 23% of marginal contributions to RSG uplift from two sources. Positive and the majority of negative deviations from DA schedules in RT account for 12% of RSG, while load that does not appear in the DA market but is obligated in the FRAC accounts for 11%. Binding constraints account for approximately 5% of the marginal contribution of RSG; this contribution captures the pure effects of congestion that might be caused by other factors, e.g., an increase in Econmax to exert locational market power, and represents the

uplift above and beyond the factor that caused the constraint to bind. Even though using a proxy for headroom, this factor appears to account for 6% of RSG uplift. Virtual supply offers (VSO) only account for increases of about 1.3% of RSG uplift; and, this finding supports the argument that VSO have only a minor impact on the incurrence of RSG. Changes in NSI during the period between the closing of the FRAC and the start of the operating day at both types of interfaces (PJM and Other Tier 1) could have a positive or negative effect depending upon whether there is a net injection or a net withdrawal. Similarly, forecast error could have a positive or negative effect depending on whether the error is an over-forecast or an under-forecast.

Table 4. Expected value of marginal contributions to RSG MWP (2006 \$/MW)

Continuous variable (lower/upper bounds in parentheses)	Whole period	Before ASM	After ASM	Assuming zero VSO
Difference in physical load committed in FRAC and cleared in DA (FRAC-DA) (GW)	0.2480 (-0.0382/0.6730)	0.2385 (-0.0490/0.6544)	0.3100 (0.0383/0.7943)	0.3464 (0.1448/0.6862)
Change in load during RT (RT-FRAC) (GW)	0.2774 (-0.0704/0.6280)	0.2327 (-0.1063/0.5724)	0.5685 (0.1613/0.9968)	0.5940 (0.3232/0.8669)
Change in offers during RT (RT-FRAC) (GW)	0.4142 (0.0830/0.7875)	0.4181 (0.0941/0.7774)	0.3892 (0.0144/0.8595)	0.8833 (0.6398/1.1681)
Change in Econmax during RT (GW)	0.4605 (0.4305/0.7030)	0.4693 (0.4411/0.7013)	0.4031 (0.3601/0.7256)	0.6795† (0.6795/0.8574)
Headroom proxy (GW)	0.1312 (-0.0036/0.2675)	0.1179 (-0.0142/0.2509)	0.2174 (0.0678/0.3762)	0.1985 (0.0958/0.3025)
Number of binding constraints	0.1124† (0.1124/0.8432)	0.1384† (0.1384/0.8517)	-0.0567 (-0.0477/0.8064)	0.1124† (0.1124/0.8432)
Virtual supply offers (GW)	0.0282 (-0.0468/0.2492)	0.0457 (-0.0299/0.2774)	-0.0858 (-0.1469/0.0615)	--
Load forecast (MISO footprint) (GW)	-0.0062 (-0.0743/0.0662)	0.0079 (-0.0562/0.0762)	-0.0979 (-0.1849/-0.0008)	-0.0062 (-0.0743/0.0662)
Change in NSI at PJM interchange between the FRAC and 12:00 a.m. (GW)	-0.0406 (-0.5596/0.4987)	-0.0232 (-0.5304/0.5038)	-0.1539 (-0.7497/0.4751)	0.1691 (-0.2086/0.5659)
Change in NSI at Other Tier 1 interchanges between the FRAC and 12:00 a.m. (GW)	-0.0577 (-0.3766/0.2679)	-0.0893 (-0.3867/0.2144)	0.1480 (-0.3055/0.6167)	-0.0577 (-0.3766/0.2679)
Change in NSI after 12:00 a.m. in RT (all interchanges) (GW)	0.6635 (0.2060/1.1358)	0.6835 (0.2488/1.312)	0.5335 (-0.0491/1.1486)	0.6635 (0.2060/1.1358)

†Due to the non-linearity of this measure, the expected value is skewed towards the lower bound.

The period since the start of ASM represents if nothing else an economic experiment where an *ad hoc* regulatory response results in some unanticipated results. One reason for the type of analysis presented here is the identification of market distortions prior to pursuing such a response or altering market rules. The FERC 'Order on Paper Hearing' issued on November 10, 2008 serves as an example of a regulatory fix with unintended consequences. The analysis presented in Table 4 supports the filing of the IMM (February 23), and further points to the distortionary impacts of the FERC 'Order on Paper Hearing'. As indicated previously VSOs were associated with only 1.3% of RSG which is substantially below the 40% used in market re-settlement. Further, with the decline in VSOs, as indicated on Table 2, RSG did not decrease correspondingly. RSG actually increased on average by slightly over 5%. However, this increase may be due to weather and other factors, and over time average hourly RSG MWP may very well

return to the average observed over the whole period and the period before ASM. What is apparent, however, from our analysis is that there was a substantial shift of the marginal contribution from generators to load serving entities. This shift is more apparent when we compare the results of our scenario (assuming zero VSO) with the entire period. These shifts indicate that load serving MPs obtain a benefit from virtual trades in the form of offsets from RSG in addition to market efficiencies arising from price convergence. Further, the comparison of the two cases indicates that a claim made in one of the early RSG filings, that VSOs cause binding constraints is probably not supportable; that is, the marginal contribution for binding constraints is the same for both the whole period and the scenario assuming no VSO. This finding supports the four testimonies filed with the FERC that the original testimony was in error.

These results point to a far more important set of insights from this type of modeling exercise. In terms of tariff design, this type of tool is important from the aspects of identifying factors causing a cost and assigning relative magnitudes of cost contribution to each cost. As the example of VSOs illustrated, targeting one factor leads to unintended results. Equally, excluding a factor will lead to unintended results. For example, internalizing RSG through changes in calculation of LMP within the MISO footprint and without a similar assessment to NSI would not necessarily lead to less RSG. This would result in a price differential between the MISO and external areas resulting in increased NSI, potentially more deviations, and increased price volatility. Quantification of the marginal contribution provides for a means of *ex ante* pricing which is absent from all of currently proposed RSG re-design methods. Further, use of this type of econometric model provides a means of updating a tariff as market behaviors change. And, in the course of that process, metrics evaluating progress towards more efficient market rules can be developed.

c. Caveats

As with any economic or econometric analysis, there are caveats that need to be observed in considering the results. Several caveats apply here. First of all, we only had access to the data publicly available on the MISO website. As a result, three variables were incompletely specified or absent. Those variables include headroom, binding constraints, and intra-hour deviations. For headroom, we were forced to define a proxy which is an imperfect measure. And, for binding constraints we did not have the actual MWs dispatched to address binding constraints. Binding constraints can occur without requiring the dispatch of a unit, and the integer number of constraints does not reflect this. Further, we had no means of defining an intra-hour deviation. As such, if these variables were either defined with the ideal or added, the results of this modeling exercise would undoubtedly change.

Also, we were restricted in our analysis to a MISO footprint level of aggregation, and hourly integrated values. At this level of aggregation information will be lost. For example, for RT deviations of load, one load serving MP could report a positive deviation or (a combination of positive and negative deviations during an hour), while another during the same hour might report a negative deviation or a combination of deviations. These deviations are summed on an hourly basis and then across the footprint, and thus in the analysis we capture an implicit netting effect. Use of nodal data would better reflect the processes that incur RSG. However, the same econometric techniques used in this analysis using aggregate data would also be applicable to nodal level data.

5. Conclusions.

The analysis presented here accomplishes a number of objectives. First of all, the analysis does demonstrate that the marginal contribution of various assumed causal factors to the incurrence of RSG in the MISO can be estimated with some relatively simple econometric techniques. This is in contrast to the MISO's response to a FERC order that this type of analysis was impossible to perform. The type of analysis presented here should be performed at the very beginning of a tariff redefinition or redesign effort to provide guidance to task forces such as the RSG TF. Once available, this type of analysis can be used to develop tariffs that provide the characteristics of good tariff design such as a basis in cost causality, *ex ante* pricing, equity, flexibility, and transparency. Also, this type of method can be used to develop metrics for progress towards reductions in uplift through a continuing process of evaluation of the marginal contributions as they change with behaviors in the market.

Second, from this analysis, we can speak directly to the issue of the association of RSG with various factors. The use of an econometric model which includes as many factors as available is preferred to the use of single factor correlation coefficients. As demonstrated by this analysis, correlation coefficients are deceptive in that they only show a possible association and do not have predictive power. To demonstrate probative evidence, a single modeling framework must be developed which includes all of the factors assumed to cause the effect. When this is done for RSG uplift at the MISO, it becomes apparent that not all factors are equally associated (or 'cause' RSG). Further, our analysis provided some surprises in terms of identifying factors that had not been previously considered as being particularly causative. As an example, both positive and negative deviations of NSI in RT proved to be one of the potentially more significant sources. On the other hand, VSOs which had been previously tagged as having a significant effect, provided one of the smallest.

Third, this approach allows us to identify some of the distortionary effects of a potential regulatory fix prior to implementation. As indicated by our discussion of the November, 2008 FERC Paper Hearing Order, and the subsequent re-settlement, the shifting of 40% of RSG to VSO was probably unfair and unjust. This also resulted in a 60% decline in virtual trades, and the exit of a number of firms from the MISO markets. This event also resulted in a shift of marginal contributions to RSG among MPs to a much greater extent than just the amounts associated with VSO. Given the evidence generated by our modeling exercise, this was predictable. Similarly, examination of the 'Indicative' and the 'Interim' tariffs along with some of the other proposed solutions suggest various aspects that would result in other distortions including increased volatility, uncertainty, and the exit of other MPs from the MISO markets. Therefore, analysis such as presented here can be used to avoid costly mistakes which cripple the wholesale market.

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