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A Review of the Transmission Mechanism of Macroeconomic Factors Affecting Electricity Prices

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Abstract. This report presents a comprehensive systematic review of 15 international and domestic publications, analyzing the transmission mechanism through which macroeconomic factors affect electricity prices across five dimensions: primary energy price transmission, macroeconomic cycle linkages, financial market mechanism design, market structure and pricing rules, and policy regulatory frameworks. Key findings include: natural gas and crude oil prices are Granger-causal sources of industrial electricity price changes, with a transmission cycle of approximately one year; a significant long-term cointegrating relationship exists between electricity consumption and GDP; financial crises exert sustained impacts on electricity demand through FDI channels; financial derivatives such as electricity futures and financial transmission rights (FTR) play crucial roles in price stabilization and hedging; while market structure factors such as the abuse of market power and information asymmetry profoundly influence the formation of electricity prices and transmission efficiency. Based on a systematic analysis of the transmission mechanism, this report proposes policy recommendations for improving China's electricity price management system, aiming to provide theoretical support for deepening electricity market reforms.

Keywords: macroeconomic factors, electricity price, transmission mechanism, electricity market, financial derivatives

1. Introduction

As one of the most fundamental factor prices in the modern economic system, electricity price not only directly affects industrial production costs, quality of life, and corporate investment decisions, but also serves as a barometer of macroeconomic performance. However, electricity price formation is not an isolated process; it is deeply embedded in multiple transmission chains of the macroeconomy, influenced by energy costs, economic cycles, financial markets, external shocks, and other multidimensional factors.

In recent years, as China's electricity market liberalization has continued to deepen, electricity prices have gradually shifted from complete government control to market-based pricing. Consequently, both the frequency and magnitude of electricity price fluctuations have increased significantly. Simultaneously, severe global energy price volatility, deepening linkages between domestic and international economies, and rising complexity in financial markets have made the

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research on macroeconomic transmission mechanisms of electricity prices increasingly urgent and practical.

This report systematically reviews 15 core publications in related fields and constructs a multi-layered analytical framework encompassing primary energy price transmission, macroeconomic indicator linkages, financial derivative impacts, market structure factor interference, and regulatory policy effects. This comprehensive analysis aims to present the transmission pathways and inherent mechanisms through which macroeconomic factors influence electricity prices, providing systematic reference for policymakers, electricity market participants, and academia [1].

2. Theoretical framework of macroeconomic factors on electricity price transmission

The transmission of macroeconomic factors to electricity prices is a systemic process with multiple layers and pathways. This report identifies five core dimensions, each having both vertical progression relationships and horizontal cross-cutting effects [1].

The electricity price transmission mechanism refers to the causal chains and dynamic processes through which macroeconomic variables influence electricity prices via supply-side cost pressures, demand-side aggregate changes, financial market signal transmission, competition pattern shifts, and institutional policy interventions. This transmission process exhibits four fundamental characteristics:

First, multidimensionality: electricity prices are simultaneously affected by production costs, market demand, financial expectations, competitive structure, and policy environment. No single factor can fully explain electricity price movements. Second, time lag: macroeconomic variables typically exert lagged effects on electricity prices. For example, primary energy price transmission to electricity prices takes approximately one year, while economic cycle impacts on electricity demand require several quarters to fully manifest. Third, nonlinearity: various factors exhibit threshold effects, stage-specific characteristics, and regional heterogeneity in their influence on electricity prices. Fourth, bidirectionality: electricity prices and macroeconomic variables typically exhibit bidirectional causality, and changes in electricity prices in turn influence economic growth, energy demand, and financial markets [2].

Based on a literature review, macroeconomic transmission of electricity prices can be categorized into five primary pathways: First, the energy cost transmission pathway, where primary energy prices (coal, oil, natural gas) influence electricity prices by affecting generation costs. Second, the economic cycle transmission pathway, where macroeconomic indicators such as GDP growth and industrial production activity influence electricity prices by affecting total electricity demand and supply-demand balance. Third, the financial shock transmission pathway, where international financial crises, exchange rate fluctuations, and FDI volatility transmit indirect effects through aggregate demand. Fourth, the market structure transmission pathway, where market concentration, bidding strategies, and market power behaviors influence electricity spot market price formation mechanisms. Fifth, the financial instrument transmission pathway, where electricity futures and financial transmission rights exert stabilizing or destabilizing effects on spot electricity prices through price discovery and risk transfer mechanisms [1,3].

3. Dominant transmission effects of natural gas and crude oil on electricity prices

Empirical research based on 23 years of monthly data (January 2001 to June 2024) from California, using VAR models and Granger causality tests, demonstrates that natural gas and crude oil prices are Granger-causal sources of changes in industrial electricity prices, while coal prices have no direct

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causal relationship with electricity prices but form an indirect transmission pathway by influencing natural gas prices.

This finding is highly consistent with California's energy structure: after 2001, the state phased out coal-fired power generation and fully transitioned to natural gas-fired power generation, making natural gas prices the most critical external factor determining local electricity prices. The optimal lag order of the VAR(11) model is 11 periods (approximately corresponding to a one-year transmission cycle), which fully reveals that energy price transmission exhibits significant long-term characteristics [4].

Variance decomposition results, as shown in Table 1, further clarify the dynamic contributions of each energy price to electricity price fluctuations: In the short term (1-period lag), electricity price fluctuations are almost entirely determined by self-inertia. As the lag order increases, natural gas price contribution to electricity price rises continuously, reaching 11.55% at the 11-period lag, becoming the most influential external variable. Crude oil contribution is moderate (approximately 6-7%), while coal contribution is minimal (approximately 2%).

Table 1. Variance decomposition results of industrial electricity prices in California

Lag Period	Electricity Price Self-Contribution	Natural Gas	Crude Oil	Coal
1 period	100%	0%	0%	0%
7 periods	86.98%	6.12%	5.55%	1.36%
11 periods	79.18%	11.55%	7.20%	2.08%
14 periods	81.23%	10.32%	6.21%	2.25%

4. Transmission effects of financial market mechanisms on electricity prices

4.1. Price discovery and stabilization functions of electricity futures

The electricity futures market plays a core role in electricity price risk management through the convergence mechanism between futures and spot prices. Taking a power generation enterprise as an example: on April 15, the enterprise anticipated selling 10,000 MWh at a spot price of 253 yuan/MWh, while simultaneously selling 100 futures contracts at 251 yuan/MWh. By July 30, when the actual spot price dropped to 247 yuan/MWh, its spot market loss of 6 yuan/MWh was offset by a futures market gain of 4 yuan/MWh, resulting in a net profit of 2 yuan/MWh and effectively mitigating the loss from the spot price decline [4,5].

Generators' bidding strategies equally impacts clearing prices. Simulation results indicate that when generators bid at benchmark prices (close to marginal cost), they obtain the maximum contract quantity (6.41 GWh) with the lowest clearing price (215 yuan/MWh).

4.2. Inherent supply risk mechanism of electricity futures

However, the introduction of electricity futures is not without risks. Game theory analysis reveals that when all rational generators face signals that futures prices higher than spot prices, they will uniformly choose not to participate in futures markets and shift entirely to spot markets, leading to electricity supply shortages at futures maturity and triggering widespread blackouts. Conversely, when futures prices are below spot prices, all generators will enter the futures market, causing supply surges at maturity that lead to grid congestion [6].

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The institutional root of this inherent supply risk lies in the fact that futures contracts are subject to cash settlement rather than mandatory physical delivery. When futures prices exceed spot prices, a supply shortage creates a Nash equilibrium among all rational generators,none of whom have a unilateral incentive to deviate; market failure becomes almost inevitable. The California electricity crisis of 2000-2001 fundamentally originated from this mechanism.

4.3. Hedging mechanism of financial transmission rights against congestion risks

Under China's Unified Settlement Point (USP) pricing mechanism, the benchmark prices of generators' mid-to-long-term contract benchmark prices shift from nodal prices to the unified settlement point price, transforming congestion price difference risk from "two-node price spread" to "price spread between generator nodes and the unified settlement point." Taking a 50 MW wind farm as an example, simulation results are presented below: [7]

Table 2. Simulation results of adaptive FTR hedging effectiveness with USP as endpoint

Scenario	Mid-long Period Settlement Revenue (10k yuan)	Total Revenue Without FTR (10k yuan)	FTR Revenue (10k yuan)	Total Revenue With FTR (10k yuan)
No Congestion	520.79	5663.98	0	5663.98
Light Congestion	57.91 (↓88.88%)	5201.09 (↓8.17%)	462.89	5663.98
Severe Congestion	-867.86 (negative)	4275.32 (↓24.52%)	1388.66	5663.98

Results demonstrate that adaptive FTR with USP as the endpoint completely eliminates congestion price risk, thus maintaining stable total generator revenue (5663.98 × 10,000 yuan) across different congestion levels. With increasing congestion severity, the necessity of FTR's hedging function becomes more pronounced, with FTR contribution reaching 24.52% in severe congestion scenarios.

5. Influence mechanisms of market structure factors on electricity prices

5.1. Relationship between bidding behavior and clearing prices

In deregulated competitive electricity markets, generator bidding behavior directly impacts market clearing prices. Simulation studies using the IEEE 39-bus system as a physical model demonstrate that the higher the bidding coefficient, the lower the contract quantity and the higher the clearing price. Generators' bidding strategies should be dynamically adjusted according to the relative relationship between futures and spot prices: when they expect spot prices to exceed futures prices, they should sell futures contracts now and buy them back at maturity to avoid downside risks; otherwise, they should operate directly in the spot market. The California electricity crisis case shows that sellers with multiple units exploited the bidding mechanism to manipulate markets and inflate prices, representing one of the fundamental mechanisms behind the 500% electricity price surge within two years, highlighting the distortionary effect of market structure defects on price transmission [8,9].

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5.2. Differentiation mechanism of transmission congestion on nodal prices

In electricity markets with transmission congestion, nodal prices will exhibit significant differentiation due to varying degrees of contribution to congestion constraints at different nodes. Simulation studies based on 3-node systems and improved IEEE 30-node systems have compared clearing results under different congestion control mechanisms: [10]

Table 3. Comparison of spot prices under different congestion management mechanisms

Control Mechanism	Congestion Eliminated	Node 3 Price ($/MWh)	Generation Cost ($/h)	Social Surplus ($/h)
No congestion baseline	—	46.34	6310.40	427.40
Generation control only	Yes	173.06	9534.26	19608.57
Load control only	Partial	51.13	—	2026.85
TCPS control	Yes	48.76	6366.70	826.57
FACTS + Load joint	Yes	47.09	5010.43	701.58

Results show that while generation control alone eliminates congestion, it causes it causes the price at Node 3 to surge to $173.06/MWh (3.73 times the baseline), with generation costsincreasing by 51.1%. In contrast, the combined FACTS (Flexible AC Transmission System) and load control mechanism achieves minimal price distortion while eliminating congestion and optimizing overall social welfare [11].

5.3. Market power distortion of terminal electricity prices in retail markets

As China's electricity spot market construction deepens, retail markets and spot markets accelerate integration. Electricity retailers inherently possess information acquisition priority and independent pricing authority relative to users, creating potential risks of abusing market power. Based on a four-dimensional six-indicator market power monitoring model, the assessment results of five retailers in a region are presented below [12,13].

Table 4. Market power monitoring results of electricity retailers in retail markets under spot market mode

Retailer	Market Share	Price Deviation Rate	Excess Profit Rate	Market Power Risk
A	17%	16.90%	6.90%	Low
B	23%	20.35%	10.35%	High
C	20%	17.48%	7.48%	Medium
D	15%	18.70%	8.70%	Medium
E	25%	20.90%	10.90%	Highest

Results show that the market HHI index is 2068 (>1800), which indicates a highly concentrated oligopolistic competitive structure. Retailer E, with the largest market share (25%), simultaneously exhibits the highest price deviation rate (20.90%) and excess profit rate (10.90%), presenting the highest market power risk. This demonstrates that retail-side market concentration directly impacts the degree to which terminal electricity prices deviate from competitive equilibrium levels.

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6. Policy recommendations and market optimization

Establish fuel cost pass-through mechanisms to promptly transmit fluctuations in primary fuel prices (natural gas, crude oil) to grid-connected electricity prices, thereby preventing power generation enterprises from bearing sustained cost inversion pressures. Implement differentiated price transmission frameworks adapted to regions with different power generation structures. Proceed in an orderly manner with futures market construction on the foundation of improved spot markets, preventing supply-demand imbalances through measures such as standardizing physical delivery proportions and optimizing market entry criteria. Prioritize futures pilot programs in provinces with strong spot market foundations, such as Guangdong and Zhejiang, and gradually expanding nationwide. Establish multi-dimensional monitoring systems including Herfindahl Index (HHI), price deviation rates, excess profit rates, and market share-to-price ratios to implement focused regulation of electricity retailers exhibiting obvious market power characteristics. Promote diversification of market participants to reduce market concentration. Promote comprehensive congestion management mechanisms combining Flexible AC Transmission Systems (FACTS) with load control, minimizing price distortions while achieving congestion elimination and maximum social welfare. For regions with high renewable energy penetration, introduce adaptive Financial Transmission Rights (FTR) mechanisms to hedge congestion price difference risks. Advance distributed information system deployment for economic dispatch, equipping power plants with intelligent databases to enable real-time sharing of economic operation parameters. Establish information linkage mechanisms between the futures, spot, and medium-to-long-term markets, so as to enhance market price signal penetration and coordination efficiency [14,15].

7. Conclusions

Primary energy prices constitute the most direct and quantifiable driving force in electricity price transmission mechanisms. Natural gas and crude oil prices are Granger-causal sources of industrial electricity price changes, with transmission cycles of approximately one year. Macroeconomic cycles and electricity prices exhibit significant bidirectional long-term relationships; electricity consumption serves as an effective proxy for GDP. Financial market mechanisms play crucial roles in electricity price stabilization and risk transfer. Specifically, electricity futures possess price discovery and hedging functions, but improper institutional design may trigger supply imbalances. Market structure factors such as the abuse of market power, transmission congestion, and information asymmetry may cause electricity prices to deviate significantly from equilibrium levels.

Institutional factors and policy frameworks constitute fundamental constraints on transmission mechanism efficiency. Variables such as unified settlement point pricing mechanisms, market competition levels, and regulatory system sophistication fundamentally determine whether macroeconomic shocks are transmitted effectively and equitably to various market participants. The transmission of macroeconomic factors to electricity prices is a systemic process characterized by multiple pathways, multiple layers, and multiple time lags. In the context of China's deepening electricity market liberalization, establishing scientifically sound price transmission mechanisms requires not only improved financial derivative markets and competitive market systems, but also systematic institutional design and differentiated regional policies.

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